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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 737

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. PROFESSIONAL PAPER March 17, 1919

# THE TOBACCO BEETLE: AN IMPORTANT PEST IN TOBACCO PRODUCTS

By

G. A. RUNNER

Entomological Assistant

[With Technical Descriptions of Coleopterous larvæ
By Adam G. Böving]

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By G. A. RUNNER, *Entomological Assistant.*

(With technical descriptions of coleopterous larvæ by Adam G. Böving.)

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## A PEST IN CURED AND MANUFACTURED TOBACCO; ITS COMMON NAMES.

The tobacco beetle or "cigarette beetle," *Lasioderma serricorne* Fabricius, which feeds and lives mainly in dried vegetable products, is by far the most destructive pest with which manufacturers of or dealers in tobacco or tobacco products have to contend. It is present at times in practically all warehouses, cigar and tobacco factories, and retail or wholesale establishments where cured leaf tobacco or manufactured tobacco is handled or stored.

This beetle is now known under several names. "Tobacco beetle," "cigarette beetle," "tobacco bug," "tobacco flea," and "tobacco flea-beetle" are the terms most commonly used in referring to it. The

NOTE.—The author, Mr. G. A. Runner, was transferred from Southern Field Crop Insect Investigations to Deciduous Fruit Insect Investigations on May 21, 1917.

last two names may have originated from confusion of the species with a field insect, the tobacco flea-beetle, *Epitrix parvula*, which attacks growing tobacco, the holes eaten in the leaf showing in the cured leaf tobacco and somewhat resembling holes made by the true tobacco beetle, *Lasioderma serricorne*. The name "cigarette beetle" has been quite generally used in entomological literature but is not suitable as it conveys the impression that the insect confines its work to cigarettes whereas it is a general feeder upon all cured tobacco products. Throughout this bulletin the name "tobacco beetle," which was used by Mr. E. A. Schwarz in earlier accounts of the insect, is adopted, as the present consideration of the insect refers to its depredations upon all forms of cured and manufactured tobacco.

FIG. 1.—Cigars damaged by the tobacco beetle (*Lasioderma serricorne*) showing burrows of larvæ and exit holes of adults.

## THE CHARACTER OF ITS INJURY.

The injury caused by the tobacco beetle is very great, owing to its habit of occupying its food substance during all stages of its life. The principal damage is done by the larva or "worm" stage, and with tobacco, as with other food substances, the actual amount consumed usually is of far less importance than is the presence of refuse, excrement, dust, and the dead beetles, which render the manufactured product unsalable.

The insect damages cigars (fig. 1) and pressed tobacco by burrowing small cylindrical tunnels which later become filled with dust and excrement. In cigars the holes may extend from one side to the other, and in some instances the holes or galleries may wind through the filler of the cigar, a large part of the interior being thus destroyed without external evidence of injury to the wrapper. The larvæ often will work between two closely packed cigars, slitting both wrappers lengthwise for some distance, and the pupal cells frequently are constructed between

two closely pressed cigars or beneath the band. Injured cigars do not draw well, burn unevenly, and dust is drawn into the

FIG. 2.—Pressed cut smoking tobacco showing burrows of larvæ and exit holes of adults of the tobacco beetle (*Lasioderma serricorne*).

mouth of the smoker. High-grade cigars, in which the more expensive leaf tobacco is used as wrapper or filler, are far more susceptible to injury than are cigars made from heavier, stronger,

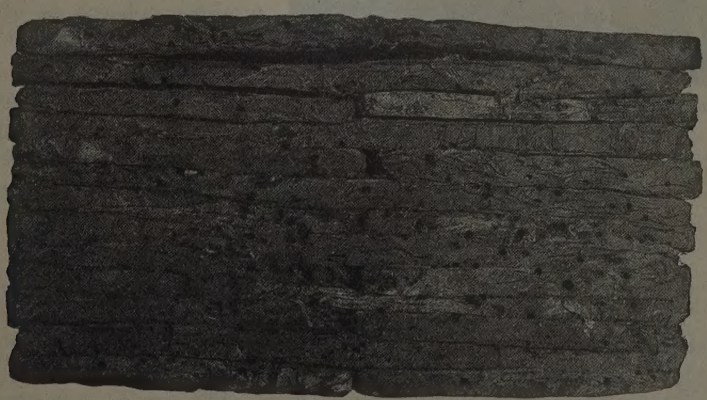


FIG. 3.—Chewing tobacco injured by the tobacco beetle (*Lasioderma serricorne*).

and inferior grades. In cigarettes, also, injury is more apt to occur in those made from the sweeter, milder types of leaf, such as is used in the more expensive grades. Fine Turkish tobaccos

are especially liable to infestation, holes being bored through the wrappers and frequently through the cork tips. The interior of the cigarette is filled with refuse, and the wrapper becomes soiled and discolored. Smoking (fig. 2) or chewing tobacco becomes badly worm eaten. In pressed kinds, such as plug tobacco and pressed and sliced smoking tobacco, galleries are formed. In pressed plug tobacco (fig. 3) the wrapper is cut and the edges furrowed. Granulated and fine-cut types become mixed with the dust and refuse from feeding and with the dead bodies of adult beetles. Pupal cells occur on the sides of the containers or in the tobacco. Leaf tobacco (fig. 4) is infested in much the same manner as cigars. The larvæ bore holes in every direction through the leaves. Fine wrapper tobacco is often so badly injured that it is worthless. In leaf tobacco used as filler, or in manufactured tobacco or snuff, the damage is confined more to the tobacco actually consumed by the larvæ than is the case with attacks of the insect on the manufactured product.

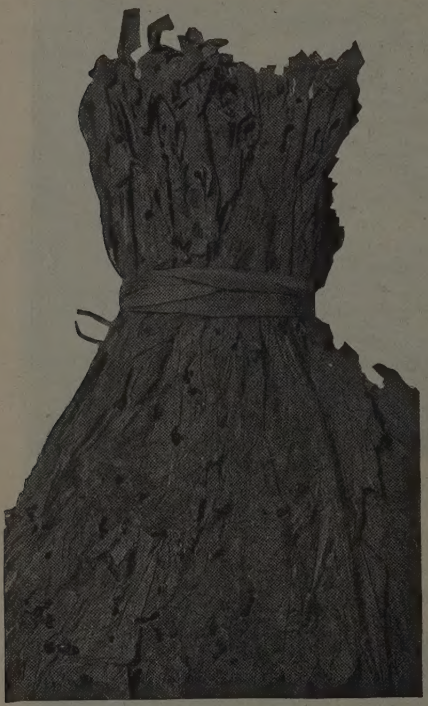


FIG. 4.—Damage to cigar tobacco by the tobacco beetle (*Lasioderma serricorne*).

## CLASSIFICATION AND SYNONYMY.

The family Ptinidae, to which the tobacco beetle belongs, is composed of small insects which rarely exceed one-fourth of an inch in length. The head is usually retracted, the body more or less cylindrical and firm, and the wing covers firm. The species vary greatly in form, and several species belonging to the family have been widely distributed by commerce. Although the family is quite large, comparatively few species are economically important and injurious;

namely, those living in stored products and timber. Among these, besides the tobacco beetle (*Lasioderma serricorne*), may be mentioned the larger tobacco beetle (*Catorama tabaci*) and the drug-store beetle (*Sitodrepa panicea*). The genus Lasioderma of Stephens contains only five known species. The tobacco beetle was first described from America in 1792 by Fabricius (1)[1] under the name *Ptinus serricornis*.

### SYNONYMY.

The following synonymy is given by Gemminger and Harold (16):

*Lasioderma serricorne* Fabricius, Ent. Syst. (1792), v. 1, p. 241; Mulsant, Ann. Soc. Linn. Lyon (1864), v. 12, p. 1, pl. 1, fig. 10; Le Conte, Proc. Acad. Nat. Sci. Phila. (1865), p. 236.

*Lasioderma flavescens* Dahlbom, Dej. Cat. 3 ed. (1837), p. 129.

*Lasioderma testaceum* Duftschmidt, Fauna Austr. (1859), Deutchl. Fauna Insecten (1837), v. 11, p. 89, pl. 237, fig. P.

## FOOD SUBSTANCES OF THE TOBACCO BEETLE.

The tobacco beetle feeds upon a variety of dried vegetable substances as well as upon a few dried animal substances. Early records describe the insect as feeding upon or living in "dried plants." Its more common food is cured or manufactured tobacco. In drug and grocery stores it is often found infesting such substances as dried roots of various kinds, pressed yeast cakes, and seeds. The writer on one occasion found a collection of dried botanical specimens in a State museum badly injured by the pest. In the course of investigations of the insect it has been reared from and found infesting or feeding upon the following substances: Cured leaf tobacco, manufactured tobacco of various kinds, such as smoking and chewing tobacco, snuff, cigarettes, and cigars; tobacco seed, dried figs, cayenne pepper, ginger, dried dates, powdered orris root, curry powder, starch, pressed yeast cakes, and dried plants of different kinds in botanical collections. When large numbers of the beetles were required at times for experimental work it was found that they could be bred most conveniently in dried yeast cake (fig. 5).

In addition to the food substances already mentioned, the insect has been reported in entomological literature as injuring or infesting opium, red pepper, rice, paprika, stock foods, turmeric, spices, saffron, licorice, bran, belladonna, and pyrethrum powder. Dr. J. B. Smith (59) also mentions injury to cane and rattan work of all kinds, books, and gun wads. Jones (77) reported the insect breeding in raisins in the Philippines. Van Dine (55) states that in the Hawaiian Islands the tobacco beetle is the most common and destructive pest

[1] Numbers in parenthesis refer to "Bibliography," p. 69.

in stored products, and that it infests groceries, drugs, and dried products indiscriminately, but possibly favors manufactured tobacco. He also reports having found the insect very injurious to wall paper and books in Honolulu.

Dried animal substances occasionally are attacked. Dried fish is mentioned as a food substance by Mackie (74), and Van Dine (55) reports the beetle as having been reared from fish guano used as fertilizer. There are also reports of leather goods having been injured. The late F. C. Pratt (53) noted injury by this species to an insect collection in western Texas, about 10 per cent of the specimens in a box of Orthoptera having been damaged.

There are numerous records of the tobacco beetle feeding upon and injuring upholstered furniture. Cook (25) has described injury to

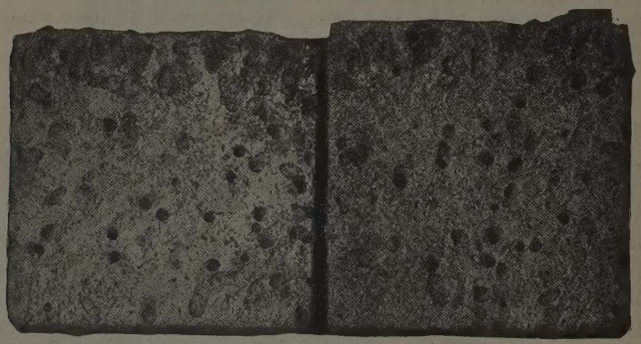


FIG. 5.—Work of the tobacco beetle (*Lasioderma serricorne*) in pressed yeast cake.

furniture, and stated that the work of the insect "made the plush covering look like a sieve." Chittenden (53, 58) has reported the insect as damaging upholstered furniture, rugs, and tapestry in dwelling houses in the District of Columbia, West Virginia, and New Jersey. Osborn (46, 49) has reported infestation of plush upholstered furniture at Columbus, Ohio. Silk as food is mentioned by Osborn (46). Injury to silk and plush hangings in France has been mentioned by Bordage (38).

The occurrence of the beetle in some of the substances given is undoubtedly more or less accidental. Attempts made by the writer to rear the beetle from the egg stage in many of these substances resulted in failure. In many instances the larvæ fed for a time but did not complete their transformation to the adult stage. In controls on these experiments adults were reared from eggs placed in yeast cakes, tobacco seed, or cured tobacco, at the same time and kept under the same conditions.

## FOOD HABITS OF BEETLES RELATED TO THE TOBACCO BEETLE.

Beetles belonging to the same family as the tobacco beetle, the Ptinidae, in general usually feed on vegetable matter in an incipient stage of decay or in dried vegetable or animal substances. A few bore into solid wood and others attack living plants.

The larger tobacco beetle (*Catorama tabaci* Guérin) feeds on tobacco and tobacco seed (fig. 6).

The drug-store beetle (*Sitodrepa panicea* Linnaeus) feeds on drug-store supplies such as dried roots and seeds, and sometimes attacks tobacco. Its food habits are very similar to those of the tobacco beetle.

*Mezium americanum* Laporte occurs in dwellings and breeds in dried animal substances. It is known to infest tobacco seed.

A species of European origin, *Ptinus fur* Linnaeus, now widely distributed by commerce, is said to be often injurious to museum specimens, and has been reported as injuring tobacco.

FIG. 6.—Cigar tobacco injured by the larger tobacco beetle (*Catorama tabaci*).

The following records of food habits of several other species belonging to the same family have been given by Blatchley (71):

*Trypopitys sericeus* Say. Occurs beneath bark and on old branches of wild cherry and oak.

*Caenocara oculata* Say. On low vegetation and in puff balls (*Lycoperdon* spp.).

*Ptilinus ruficornis* Say. Larvæ bore into dead branches of oak and maple.

Some species of Ptinidae bore into decaying timbers of houses. The ticking sound made has given these insects the name of "death-watch" beetle.

## LOSSES DUE TO THE TOBACCO BEETLE.

Losses occasioned by the tobacco beetle, either directly or indirectly, occur to some extent in every place where cured or manufactured tobacco is handled. Various statements have been received from manufacturers which show that loss at the factories is very large, but this probably represents only a small part of the loss due to damaged cigars, cigarettes, and manufactured tobacco in the hands of jobbers and retailers. In many factories the loss is estimated to be more than $5,000 a year. An agent of this bureau, on one occasion, in a single factory, was shown 14 barrels of damaged and worm-eaten cigars, part of these having been made from the finer and more ex-

pensive grades of Cuban tobacco. The loss from the beetle in this instance was estimated at not less than $7,000, and the damage occurred within a period of only 12 months. At the storerooms of a large jobbing concern in one of the Northern States the writer was shown a lot of smoking and chewing tobacco of various brands said to weigh over one-half ton which was infested and worthless. Part of this tobacco showed injury from mold, but a large part of the damage had been caused by the tobacco beetle. In 1913 a large tobacco firm reported to the Bureau of Entomology that its loss from the beetle amounted to fully $25,000 per annum. The average annual loss in the Philippines per factory for cigars actually destroyed in the factory is said to vary from 6,000 to 13,000 pesos ($3,000 to $6,500) (77). The total money loss in the Philippines from returned cigars which are infested with the beetle has been reported by Mackie (74) to exceed 500,000 pesos ($250,000 U. S. currency) per annum. The actual money loss to the manufacturers from tobacco products returned to the factory represents only a small part of the entire loss caused by the beetle. An enormous loss occurs through damage to hogshead tobacco of certain types, and, as in the case of manufactured or baled tobacco, it is impossible to make even an approximate estimate of the loss. In 1911 Mr. J. Matsumura, inspector of the bureau of monopolies for the Imperial Japanese Government, reported that in a shipment of 60 hogsheads of American tobacco to Japan 50 hogsheads had been so badly damaged by the beetle that the tobacco was almost worthless. In exported hogshead tobacco the lighter types, such as are used in the manufacture of cigarettes, are most susceptible to injury, and a comparatively slight infestation at first may result in a heavy infestation after a long sea voyage through warm or tropical waters. The specially favorable breeding conditions brought about by high temperatures and humidity incidental to long oversea shipments make the beetle unusually destructive to cigars shipped to the United States from the Philippines. A number of dealers have reported serious loss from this source, the infestation spreading to cigars and other classes of manufactured tobacco kept in stock.

Although the tobacco beetle is present and causes more or less loss in all parts of the United States, investigations of the Bureau of Entomology show that damage is greatest in the States bordering on the Gulf of Mexico. One large manufacturer reported that his loss due to infestation of goods, chiefly smoking and chewing tobacco, shipped to the Gulf States had been so great, fully 50 per cent of the manufactured tobacco becoming wormy, that his company had been forced to restrict its activities in that section. To replace this damaged stock made their business in that section unprofitable. The factory was said to be practically uninfested, and few complaints of damage

came from other sections of the country where the same class of goods was shipped. In another instance a firm manufacturing high-grade cigars some years ago organized a separate department in which scrap tobacco was worked up into cheaper cigars. At first this department showed an annual profit of about $7,000. The beetle, however, finally became so destructive to this class of goods, and so many shipments were returned to the factory, that this branch of the business was discontinued.

The extent of injury to baled domestic tobacco can not be accurately determined until the tobacco is finally used, and, as with other classes of tobacco, it is difficult or impossible to obtain even an approximate estimate of the total loss.

In wholesale and retail drug stores the insect frequently becomes a serious pest and causes heavy loss by consuming or by making unsalable more expensive products.

## DISTRIBUTION AND DISSEMINATION.

Commerce has served to distribute the tobacco beetle widely and it probably now occurs in all countries having a temperate, subtropical, or tropical climate. In warm tobacco-growing countries such as Cuba, Porto Rico, and the Philippines, where the beetles are numerous and breed continuously throughout the year, they are being constantly exported in shipments of cigars or bales of cigar tobacco. Examinations of warehouses in which bales of infested cigar tobacco are stored, at ports of entry in this country, have shown them at times to be heavily infested with the beetle.

There has been a very noticeable increase and spread of the tobacco beetle in tobacco factories in the United States within comparatively recent years. Experienced tobacco dealers and tobacco manufacturers attribute this to the general use of steam in heating factories. The higher and uniform temperatures which are thus maintained make breeding conditions more favorable.

In tobacco factories and buildings in which tobacco products or suitable food substances are stored the insect spreads by crawling or by flight. The adult beetle is capable of flying for a considerable distance. Beetles escaping from cars or ships in which bales or hogsheads of leaf tobacco are shipped find their way to suitable food substances which then in turn become new centers of infestation and dispersion. As the life cycle of the beetle is comparatively short in warm weather, hogsheads of export leaf tobacco, slightly infested when sent out, may become heavily infested *en route* and almost worthless after a long sea voyage, the high temperature and moisture in the hold of a vessel creating ideal conditions for reproduction.

The insect is now so generally disseminated throughout the country that it is a common occurrence to find it in show cases, storage rooms,

or humidors in cigar stores. Records of returned shipments at cigar and tobacco factories show that the majority come from retailers in the Southern States and from localities where climatic conditions are especially favorable for the rapid increase of the beetle. In view of this fact it will be seen that the return of damaged goods to the manufacturers does not necessarily mean that the tobacco or cigars were infested when shipped from the factory, the actual source of infestation often being the retail store or distributing point. Even in summer few complaints come from dealers in certain of the Northern States and in Canada. Tobacco infested when shipped from the factory would certainly show damage in such localities if kept even for a short time in warm weather, as experiments made by the writer have shown repeatedly.

Tobacco may become infested also in the hands of the retailer, the beetles coming from other food substances such as yeast cakes in grocery stores, or from vegetable substances used as drugs.

In cigar or tobacco factories the beetles are being constantly introduced in bales or hogsheads of imported leaf tobacco. Cigar manufacturers frequently keep bulk tobacco in bonded warehouses at the port of entry until needed for fabrication. In many instances the bales of tobacco remain in bond for a considerable length of time. A large part of this tobacco comes from Cuba, where the beetle reproduces continuously throughout the year, and infested bales are brought into the warehouses with every shipment.

## ORIGIN AND HISTORY.

The original habitat of the tobacco beetle is not definitely known, but probably the insect is native to warm or tropical parts of America. When it was first described from America by Fabricius (1) in 1792 tobacco was not mentioned specifically as food, but the insect was reported as infesting "American dried plants."

The earliest account of injury to tobacco seems to have been that by M. Planche (38), an inspector of tobacco factories, who reported in 1848 that the insect had been found at Paris for the first time in tobacco. It was thought to have been introduced from America. Since 1848 there have been many references to the species in entomological literature as destructive to tobacco and to various dried vegetable substances.

Chevrolat (13), in 1861, stated that the insect attacks cured tobacco, that it is acclimated in all parts of the world, and that in his collection were specimens from both Americas, Algeria, Syria, Germany, and Denmark. Le Conte (15), in 1865, mentioned the beetle as having been carried by commerce over the entire globe, and stated that it lives chiefly, although not exclusively, upon tobacco. Mr. E. A. Schwarz (20), of the Bureau of Entomology, in 1883 stated that

it is a well-known pest in many cigar factories in the United States. It seems to have been only within comparatively recent years, however, that the insect has attracted attention as a serious pest in fabricated tobacco. Since the earliest days of the colonies tobacco has been an important crop and one of the main exports of several States. In Colonial times laws regulating the tobacco industry were very exacting and rigidly enforced, and for a long series of years tobacco for export which failed to come up to the legal requirements as to quality and soundness was destroyed. In view of these circumstances it seems strange, if damage to stored tobacco from insects had occurred to any great extent, that the fact was not recorded.

## ECONOMIC HISTORY.

From an economic standpoint the history of the species begins with the paper by G. F. Atkinson (21), published in 1885–86. An account of the occurrence, habits, and life history of the insect is given and emergency remedies and means of control are discussed. In 1889 the same investigator published an account of the insect, its life history, remedies, etc., in a report (22) of the South Carolina Agricultural Experiment Station.

Prof. C. V. Riley (31), in 1892, reported the insect as injuring chewing tobacco in Baltimore. He discussed its habit of flight and recommended that windows be closed at night to prevent its entrance. Steaming is given as the best means of killing the larvæ and eggs.

In 1898, in a report upon insect enemies of tobacco, Dr. A. L. Quaintance (40), then State entomologist of Florida, described injury to stored tobacco caused by the beetle, giving an account of habits, food substances, and method of treatment of infested tobacco with carbon disulphid.

Dr. L. O. Howard (42), in 1899, in an article on tobacco insects, gave a general account of the tobacco beetle and other insects injuring stored tobacco, and suggested many practical means of control. Fumigation with carbon disulphid, steam sterilization, and other repressive measures applicable to factory and warehouse conditions were described.

In 1904 Prof. T. B. Symons (51) gave results of experiments in fumigation with hydrocyanic-acid gas and carbon disulphid. Dr. F. H. Chittenden (53), of the Bureau of Entomology, conducted experiments with hydrocyanic-acid gas against the beetle in furniture in 1905.

In 1909 Mr. J. S. Houser (65) reported the beetle extremely destructive in Cuba, and stated that infested tobacco may be fumigated with carbon disulphid or hydrocyanic-acid gas without injury.

The results of experiments with dry cold storage in treating infested tobacco in Brazil were given by Gustav Pook (69) in 1910.

It is stated that the method was in use throughout Brazil and that unusually good results had been obtained.

During the same year (1910) Mr. A. C. Morgan, of the Bureau of Entomology, in an article on insect enemies of tobacco in the United States (70), briefly described methods of treatment with fumigants. It was stated that no method entirely satisfactory had been found for the treatment of baled tobacco. The results of experiments with Röntgen or X rays in the treatment of infested tobacco, conducted by Mr. A. C. Morgan and the writer, were published in 1913 (76).

From Manila, P. I., in 1913, Mr. Charles R. Jones (77) published the most comprehensive article on the tobacco beetle which had yet appeared. The life history and seasonal history of the insect in the Philippines were determined and many practical methods of control tested under cigar-factory conditions. An exhaustive series of tests with hydrocyanic-acid gas showed this fumigant to be effective in treating infested cigars without affecting their quality.

Storage of infested tobacco at low temperatures is recommended by Mr. D. T. Fullaway (79) in a publication of the Hawaii Agricultural Experiment Station in 1914. In 1916 the results of experiments with Röntgen or X rays on different stages of the beetle were published by the writer (86). In 1917 the writer (89) published a general account of the species, its life and habits, and methods of control.

In the historical sketch given only the more important publications relating to the life history of the insect or to the measures employed in its control have been cited. In the bibliography (p. 69–77) reference will be found to most of the papers, relating to the insect, which have been published in permanent form. A synopsis is given of the contents of the more important publications.

## DESCRIPTION OF STAGES.

### THE EGG.

(Pl. I, fig. 8.)

Egg about 0.45 mm. (0.44–0.46 mm.) long and 0.2 (0.19–0.21 mm.) in diameter; ovoid elliptical, pearly white, becoming more opaque and dull in color just before hatching. Surface smooth, without reticulation or sculpture except a portion at the end from which the larva emerges, which is covered with numerous papillæ.

### THE LARVA.[1]

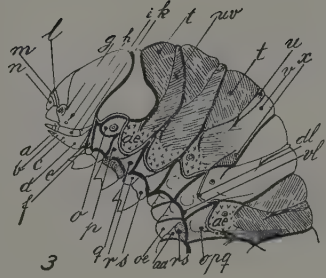
(Pl. I, figs. 1–7.)[2]

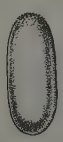
#### GENERAL CHARACTERS.

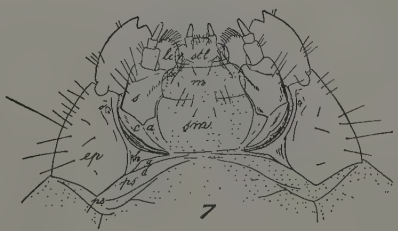
Ventral side of epicranium not continued behind the posterior end of hypostoma and its tentorial pits; gula transverse, laterally attached to the posterior

[1] In order that the identification in the field may be as accurate as possible it is necessary from time to time to incorporate in an economic bulletin technical descriptions. These descriptions are drawn up after extremely careful study of the anatomy of the larva by a specialist on the group. The following descriptions, kindly prepared by Dr. Adam G. Böving, will be of great assistance in future studies of ptinid larvæ. First is presented a description of the characters common to many ptinid larvæ, then the characteristics of the genus, and finally the specific characters of *Lasioderma serricorne*.

[2] Description of larva (with Pl. I, figs. 2–7) made by Dr. Adam G. Böving.







## EGG AND LARVA OF THE TOBACCO BEETLE (LASIODERMA SERRICORNE).

FIG. 1.—Front view of face. FIG. 2.—Side view of larva. FIG. 3.—Thoracic and abdominal areas: *aa*, Parasternum; *a*, labial palp; *ae*, alar area; *b*, stipes labialis; *c*, mentum; *d*, submentum; *dl*, dorso-lateral suture; *e*, gula; *f*, presternite; *g*, antenna; *h*, ocellus; *i*, stipes maxillaris; *k*, cardo; *l*, epistoma; *m*, clypeus; *n*, labrum; *o*, preepipleurum; *oe*, basisternum; *p*, epipleural lobe; *q*, postepipleurum; *r*, prehypopleurum; *s*, posthypopleurum; *t*, prescutum; *u*, scutum; *v*, scutellum; *vl*, ventro-lateral suture; *x*, postscutellum. FIG. 4.—Anterior portions of face (labrum, clypeus, epistoma, and frons): *Ant*, antenna; *c*, clypeus; *el*, epistoma, lateral part; *em*, epistoma, median part; *f*, frons. FIG. 5.—Prothoracic leg. FIG. 6.—Mandible, ventral side. FIG. 7.—Underside of head: *a*, Maxillary articulating skin; *c*, cardo; *ep*, epicranium; *g*, gula; *h*, hypostoma; *lc*, lacinia; *m*, mentum; *o*, ocellus; *ps*, presternum; *sm*, submentum; *stl*, stipes labialis; *x*, process between lacinia and hypopharynx. FIG. 8.—Egg. (Figs. 1 and 8 drawn by Joseph D. Smith; figs. 2–7 drawn by Adam G. Böving.)

margin of the hypostomal triangles, anteriorly adjoining submentum, posteriorly adjoining the presternites; occiput directed obliquely downwards and forwards. Mouthparts hypognathous; labrum and clypeus present; antenna small, situated at the anterior corner of frons, separated from basal skin of mandible by a narrow chitinous bridge; maxillary palp three-jointed, no definite palpiger; submentum and mentum the conspicuous parts of the ventral side of head; maxillary articulating area simple, neither chitinized nor subdivided into two or more separate lobes; stipes labialis with well developed ligula, labial palpigers, and palpi; hypopharyngeal chitinizations not developed. Tentorial bridge broad; hypopharyngeal bracon present. Body curved, wrinkled, fleshy, whitish. Legs developed; with several joints; last joint clawlike; no real claws; prehypopleurum and posthypopleurum indicated but not chitinized. Prothorax with small presternites fused into a narrow, transverse band; no separate prebasisternum; no sternellum; poststernellum well developed; mesothorax and metathorax with well developed epipleural median lobe closely connected with the alar area; spiracle-bearing preepipleurum not reaching the presternum; no definite sternellum; mesothorax with and metathorax without poststernellum. Abdominal segments ten; prescutal area large, protuberant; dorsal parts of scutum and scutellum not developed into ampullatory lobes; epipleurum bulged; parasternum anteriorly limited by a straight line; ninth abdominal segment without cerci or any chitinizations. Spiracles annuliform; mesothoracic spiracle apparently prothoracic, the preepipleurum of mesothorax being pushed forwards; metathoracic spiracle rudimentary; eight abdominal spiracles.

GENERIC CHARACTERS.

In the family Anobiidae (Ptinidae), the genus Lasioderma, belonging to the group Ptinini, is characterized as follows: Head rounded, not deeply sunk into prothorax; epistoma strong, rigid, with median region only slightly concave, and lateral regions subrectangular, projecting, not divided by any depressions; labrum subrectangular, with straight anterior margin and rounded corners; clypeus somewhat broader, subrectangular; one ocellus; antenna two-jointed, with large terminal sensory papilla; mandible with bidentate apex and convex, irregularly serrated cutting edge; no molar part or prostheca; maxillary lacinia single, broad, flat, semiovate, spinose, extending from distal end of stipes; at its base arising from the boundary region between hypopharynx and stipes maxillaris a freely projecting, somewhat shorter, four times narrower, lanceolate, spinose structure; stipes labialis broad and short; mentum somewhat large, transversely subrectangular, separated from the still broader, trapezoidal submentum by a straight, rather faint line; maxillary articulating lobe small; gula very narrow. Legs five-jointed; tarsal joint distinct, falciform, clawlike. Prothorax with tergum outlined like a dumbell, the alar areas being lobate, much larger than the upper tergal part; no chitinous linear impression between alar area and the upper tergal part. Mesothorax and metathorax both with sharply defined prescutum; scuto-scutellar parts fused. The first seven abdominal segments with a large prescutum, a narrow scutal fold, and a large scutellum; the tergal parts of the last three abdominal segments not divided; tergal folds dorsally and laterally granulated, but without transverse series of stout, backwardly curved spinules; tenth abdominal segment well developed, with two large, cushion-like pads on each side of a linear, vertical, anal fissure. Last spiracle no larger than the preceding abdominal spiracles.

SPECIFIC CHARACTERS.

Median region of epistoma with a row of five setæ on each side, lateral regions naked; labrum with about seven straight setæ on the upper surface at each anterior corner, several long, medianly curved setæ along the anterior margin and an oblique row of three, shorter, stouter, hook-shaped setæ on the under surface on either side of and posteriorly approaching the median line; clypeus naked; stipes labialis, mentum, and submentum with long soft setæ; maxillary articulating area not setiferous.

LARVAL INSTARS.

First-instar larva 0.55 to 1.4 mm. long; yellowish white; the digestive tract showing darker; body set sparsely with very long, pale hairs; head 0.12 to 0.16 mm. long. Second-instar larva about 3 mm. long; yellowish white; head 0.22 to 0.24 mm. long. Last-instar larva about 4 mm. long; yellowish white; set entirely with long, silky, yellowish brown hairs; chitinous parts brown; spiracles concolorous with body; head 0.5 to 0.7 mm. long.

THE PUPA.

Pupa (Pl. II, fig. 2) uniformly white when first transformed. Length (average) 3.5 mm. (2.5–3.75 mm.); width about 1.7 mm. (1.1–2 mm.); tips of elytra attaining fourth visible ventral segment of abdomen. Metathoracic legs beneath the elytra not attaining tips of inner wings. Head bent upon thorax and beneath pronotum. Ultimate and penultimate abdominal segments ventrally each with a pair of fleshy lateral protuberances.

THE ADULT.[1]

(Pl. III, fig. 1; text fig. 7.)

Elongate-oval, moderately convex. Uniform dull reddish yellow or brownish red. Head broad, eyes small. Antennæ rather narrow, second and third joints smaller than first, the third distinctly triangular; fourth to tenth about as wide as long; eleventh oval. Thorax strongly convex, front angles acute, hind angles wanting. Punctuation of entire upper surface fine, uniform, not dense. Length 2.2 to 3 mm.

FIG. 7.—The tobacco beetle (*Lasioderma serricorne*): Antenna of adult. Greatly enlarged.

## LIFE HISTORY AND HABITS.

### SUMMARY OF LIFE HISTORY.

The life history of the tobacco beetle may be briefly summarized as follows:

In material kept constantly warm, breeding is continuous and there may be as many as five or six generations in a year. Under usual conditions in warehouses in the latitude of Virginia there are ordinarily three or four generations a year. The beetle lives in its food substances during all stages of its existence, and the time required to complete its life cycle depends mainly upon temperature and may be as short as 45 days. Normally, in summer, the time

[1] Description of adult by W. S. Blatchley (71).

varies from 45 to 70 days. Eggs are deposited in the food substance, and under usual conditions the incubation period is from 6 to 10 days, the larval period from 30 to 50 days, and the pupal period from 6 to 10 days. Adults live ordinarily from 3 to 6 weeks after emergence. In cold climates the species passes the winter mainly in the larva stage. It thrives best in localities where the temperature and humidity are high, and in substances in which the larvæ are protected from rapid evaporation.

## THE EGG.

### PERIOD OF INCUBATION.

The time required for hatching depends upon the prevailing temperature and probably upon moisture conditions, although considerable variation in the incubation period has been observed, even with eggs from the same female which were kept under identically the same conditions. The variation in the time required for hatching is least when the eggs are not subjected to extreme changes of temperature and humidity, and when the temperature is relatively high. At Key West, Fla., where the temperature is remarkably even, the incubation period varied from 5 to 10 days in numerous experiments conducted in April and May. During the experiments the maximum temperature ranged from 91° to 93° F., and the minimum from 81° to 83° F. The average period of incubation was found to be approximately 7 days.

The length of the egg stage at room temperature at Clarksville, Tenn., in May, ranged from 7 to 14 days. In 22 records obtained during July and August the average period of 7.6 days was recorded.

At Appomattox, Va., at room temperature in July, the average period of incubation was found to be 8.2 days. The shortest period observed was 6 days and the longest period 14 days.

Records obtained at Tampa, Fla., in July and August, show an average incubation period of approximately 8 days. The longest period observed was 10 days and the shortest period 6 days.

In determining the incubation period at a fixed temperature at Richmond, Va., eggs were kept in an electrically heated and automatically regulated incubator. The temperature was fairly constant at 30° C. (86° F.) and the relative humidity at about 80 per cent. During the period of incubation the variation in temperature was less than 1° C. All eggs used in the experiments were obtained from beetles kept in the incubator, the incubation period ranging from 6 to 8 days. In all of 20 different experiments hatching commenced during the sixth day.

## THE LARVA.

Injury to tobacco by feeding is caused mainly by the larva or worm stage of the insect. It is this stage of the tobacco beetle that is often referred to by tobacconists as the "grub." Within the egg the embry-

onic larva lies with the head at the rough end, and when development is complete it eats its way through the shell in this position. Larvæ hatching in glass vials at the laboratory were observed to consume the eggshells almost completely when food was not provided. In rearing the insects for experimental work the young larvæ were often observed to live without food for periods of from 5 to 10 days. On emerging from the egg they are much more active than at other stages of growth and are capable of crawling a considerable distance in search of suitable food. Their activity at this stage accounts for the rather strange infestation of tobacco products, as the extremely minute worms readily enter very small openings in the boxes or containers. On hatching the larvæ are semitransparent, gradually assuming a whitish or creamy color as they become more fully grown. The food within the alimentary canal, seen through the skin, gives them a dark or dirty color, which varies with the amount of food present. When feeding on tobacco the fine particles of dust adhering to the minute hairs of the larvæ give them a brownish appearance, which is more noticeable in the last instar. The larvæ appear more robust, deeply wrinkled, and grublike as they become more fully grown. The young larva lies and crawls extended to full length; the older larvæ usually assume a curved position and are not so active as those newly hatched. At all stages of growth they are negatively phototropic, and when exposed to light disappear within the food substances as quickly as possible.

Larvæ of all ages are capable of crawling for a short distance and often migrate from infested to uninfested material. This habit often accounts for the quick appearance of injury in freshly made cigars. Partly grown larvæ have been found on the cigarmakers' tables and on the pickers' tables. They easily enter the open ends of the cigars that are being handled, and in a very short time their work can be noticed in the bundle or box of cigars. In a box of injured cigars examined, the work of a single larva was traced through four cigars. In another instance, in a box of sliced plug smoking tobacco, a single larva had cut a furrow in the tobacco for almost the entire distance across the top of the slices between the oiled paper covering and the tobacco.

It has been observed by leaf-tobacco dealers that a crop of Cuban tobacco which remains raw and does not cure quickly is apt to be damaged more by the beetle than the same type of tobacco which matures and cures properly. Under laboratory conditions a test was made at Richmond, Va., in 1914, with several types of leaf tobacco which confirms observations made in warehouses and factories. Similar quantities of different kinds of tobacco were closely packed in a tight container and several thousand eggs of the beetle scattered

over the top, about the same number being placed on each "hand." The box, thickly wrapped with cloth and paper to avoid sudden changes in temperature, was kept in a warm place where proper breeding conditions could be maintained. At the end of three months the tobacco was examined. The degree of infestation found is given in Table I.

TABLE I.—*Preference shown by larvæ of the tobacco beetle (Lasioderma serricorne) for different types of leaf tobacco.*

| Type of leaf tobacco. | Egg distributed. | Tobacco examined. | Degree of infestation. |
|---|---|---|---|
| Virginia heavy dark export, smoke-cured | July 10, 1914 | Oct. 10, 1914 | Slight. |
| Tennessee heavy dark export, smoke-cured | do | do | Do. |
| Burley, medium grade | do | do | Moderate. |
| Ohio cigar leaf, medium-grade filler | do | do | Do. |
| Cuban cigar leaf, Santa Clara, medium light | do | do | Heavy. |
| Florida shade-grown, light cigar wrapper | do | do | Do. |
| Carolina bright yellow, flue-cured (thin and poorly cured) | do | do | Do. |

Strong, heavy types of leaf tobacco ordinarily are not injured to any great extent unless stored for a long time. Leaf tobacco which is "fire" or smoke cured, such as that grown in the "dark-tobacco" sections of Virginia or the "black-patch" sections of Kentucky and Tennessee, is seldom seriously injured. This, perhaps, is due in part to the flavor or quality given the leaf by the smoke, which acts as a repellent, whereas the same type of leaf flue cured is readily attacked, although not to so great an extent as are lighter-bodied types of tobacco. These types, as well as all others, however, are more apt to suffer injury after the leaf has aged. The changes brought about by long storage of any tobacco seem to make it more suitable as food for the beetles.

### LENGTH OF LARVA STAGE.

At ordinary room temperatures in summer the larva or feeding stage extends over a period of from 30 to 70 days; the length of the period depends mainly on temperature and on the character and condition of the food substance. There is always considerable variation in the length of the larval period, even with larvæ from the same egg lot, kept in the same food substance, and under the same conditions. In cold weather the larvæ become dormant and may remain in this condition for several months. The insect passes the winter mainly in this stage in cool climates. When the larvæ have finished feeding and are encased within the pupal cells, they are able to stand considerable cold and are more resistant to the action of fumigants. Activity in the larva stage ceases at temperatures ranging from 60° to 67° F. At Clarksville, Tenn., larvæ which

hatched about November 10, 1915, and when partly grown were placed in granulated smoking tobacco and kept in a cool room did not transform until April, 1916. The material was protected from severe freezing, but only a small proportion of the larvæ survived the winter. The most favorable conditions for the rapid development of larvæ are created by (1) suitable food substances in compact or concentrated form, (2) high and uniform temperature, (3) high humidity, (4) protection from strong light, and (5) protection from rapid evaporation. At Richmond, Va., during the period between August 1 and November 19, 1914, the shortest larval period observed in six lots of about 20 larvæ each was 39 days, and the longest period was 61 days. Pressed chewing tobacco was used as food. The maximum temperature during the period was 91° F. and the minimum temperature was 51° F. At Key West, Fla., during the period between April 16 and June 24, 1912, in cigars kept at room temperature, the shortest larval period observed was 42 days and the longest period 66 days. The temperature of the room varied from 80° to 94° F.

Numerous experiments have shown that with concentrated foods the larval period is shortened somewhat. In several experiments with different foods kept under the same conditions in an automatically regulated incubator at a constant temperature of 86° F. the larval periods were as follows: In tobacco seed, 2 experiments, 29 and 30 days; in pressed yeast cake, 2 experiments, 27 and 30 days; in pressed plug chewing tobacco, 29 days; in sliced plug smoking tobacco, 30 days; in loose granulated tobacco, 2 experiments, 35 and 38 days; in cigars, 2 experiments, 34 and 36 days; in cigarettes, 42 days.

At Clarksville, Tenn., the following records for the larva stage were obtained at room temperatures during summer:

TABLE II.—*Length of larva stage of the tobacco beetle (Lasioderma serricorne), Clarksville, Tenn., 1914.*

| Record No. | Egg hatched— | Larva formed cell— | Larva pupated— | Days as larva. | Food. |
|---|---|---|---|---|---|
| 1 | June 7 | July 18 | July 22 | 45 | Pressed plug tobacco. |
| 2 | do | Aug. 5 | Aug. 17 | 71 | Do. |
| 3 | do | Aug. 7 | Aug. 11 | 65 | Do. |
| 4 | do | Aug. 11 | Aug. 16 | 70 | Do. |
| 5 | June 19 | July 16 | Aug. 20 | 31 | Tobacco seed. |
| 6 | June 25 | July 30 | Aug. 2 | 38 | Do. |
| 7 | June 30 | No record | July 25 | 25 | Do. |

THE PUPAL CELLS.

After the larva has become fully grown and is ready to transform into the pupa stage it forms, in any convenient place, the cell or cocoon in which transformation takes place. Apparently no special

effort is made by the larvæ to reach the surface of the food substance although many of the cells are constructed on the outside. In leaf tobacco the cells usually are formed along the midrib or in the folds of the leaf. In boxes of cigars, cigarettes, and smoking tobacco cells may be found on the sides of the boxes, often within the paper lining; others may be found between closely packed cigars or cigarettes. The larva frequently cuts through the wrapper or binder of a cigar from the outside, forming a cell just within the wrapper, the cell filling the opening made in the cigar. The pupal cells usually are ovoid, but vary considerably in shape and completeness, this depending largely on the location of the larva and the character of the food substance. They average (inside measurement) about 4.5 millimeters long and 3 millimeters wide. They are often without definite shape, flimsy, and fragile, being constructed of small particles of the food substance and refuse cemented together by a secretion of the larvæ. On several occasions larvæ were observed to leave partly formed cells, crawl a short distance, and form other cells in which transformation to the pupa stage finally took place. In leaf tobacco the cells frequently are incomplete, the larvæ utilizing folds of the leaf for part of the cell, and on flat surfaces they simply form coverings over themselves. Within dense substances the surrounding material forms the necessary protection, the walls of the cell being thinly lined.

### THE PREPUPA.

Before transformation there is ordinarily a period of from 4 to 12 days during which the larva within the cell undergoes structural changes preparatory to pupation. If exposed to low temperatures, as has been stated, the larva may remain in the cell for a considerable time before marked change in structure or appearance takes place. Before changing to the pupa stage the larva lies in a curved position within the cell, which is large enough to permit free movement. The body contracts and becomes somewhat more deeply wrinkled.

### THE PUPA.

When newly formed the pupa is white (Pl. II, fig. 2), but gradually it assumes a brownish tinge before transformation to the adult stage, the eyes becoming reddish or reddish brown. It lies on its back within the pupal cell. Should the cell be broken open and the pupa removed, transformation takes place in an apparently normal manner if protected from rapid evaporation. In handling infested leaf tobacco many bare pupæ can be seen which have been dislodged from the fragile cells or cocoons between the leaves of the tobacco. After transformation has taken place a portion of the pupal skin frequently adheres for a short time to the tip of the abdomen.

The duration of the pupa stage of the tobacco beetle at room temperatures during the warmer months of the year in several localities was as follows: At Key West, Fla., between May 13 and June 4, the average time as shown by 10 records was 6 days and the shortest period 5 days. At Richmond, Va., the average of 11 records at room temperatures was 7.8 days, the shortest period 6 days, and the longest period 12 days. At Appomattox, Va., the average of 12 records obtained during July and August was 8.1 days. During September three records show pupal periods of 7, 8, and 9 days, respectively. At Clarksville, Tenn., 3 records secured during April and May show an average of 13.6 days, and 10 records during the period between July 29 and October 1 an average of 7.8 days. At Tampa, Fla., 21 records during July show an average of approximately 7 days, and 6 records during October show an average of 8.1 days.

### THE ADULT.

When transformation to the adult stage has taken place the beetle lies inactive within the pupal cell for a period of three to seven days—usually about five days. After emergence it remains at rest for a day or more on the outside of the cell; the color of the beetle gradually becomes darker, and the normal shade of brown is reached about the time it has completed the resting period. The beetles are comparatively soft immediately after transforming and do not attain their final degree of hardness until they are ready to move away from the pupal cell.

The adults vary greatly in size. This undoubtedly is due to breeding conditions, the quality or abundance of food obtained by the insect while in the larva or feeding stage being the most important factor. The females will average larger in size than the males and they are also less active. In the vicinity of infested warehouses or factories beetles frequently are found in surrounding dwellings, and on several occasions were observed by the writer to fly from one tobacco warehouse to another located on the opposite side of the street. They avoid intense light, moving about most actively in subdued light or in darkness. When in the dark they are attracted toward subdued or artificial lights, and in tobacco warehouses often may be found in great numbers at the windows in late afternoon, the flight toward the windows being heaviest at sunset. Observations made at regular intervals throughout the night in a cigar factory showed that they were taken at a trap light at all hours of the night. During the day the greater number will be found in secluded places, such as crevices in the walls, or along the casings of windows, and within the leaf tobacco. When at rest the head and thorax are drawn downward (Pl. III, fig. 1). They have a habit of feigning

death when disturbed, the head and thorax being bent downward and the legs drawn closely together.

### MATING.

The adults generally begin to mate the second or third day after leaving the vicinity of the pupal cell. Mating in some cases occurred the first day, and was observed to take place several times during the egg-laying period.

### PROPORTION OF SEXES.

The proportion of females seems to be somewhat greater than that of the males. Four lots which had emerged at different times from material kept at the laboratory gave a total of 36 males and 41 females. One hundred beetles collected at lights at a tobacco warehouse at Danville, Va., were dissected by Mr. S. E. Crumb, of the Bureau of Entomology, and of these 36 were males and 64 females.

### LENGTH OF THE ADULT STAGE.

The length of life of the adults depends largely upon the temperature after emergence. In summer, or in rooms kept constantly warm, the beetles die much sooner than do those which emerge during cool weather. Normally the adults die in from 3 to 6 weeks after emergence. Although the mouth parts and digestive tract of the adult beetle apparently are complete and they are capable of gnawing through tobacco or other food substances to escape from the locality of the pupal cell, little if any evidence of feeding has been observed. Large numbers of adults, directly after emergence, were put in sealed tubes containing cigars, the open ends of the cigars being sealed to prevent entrance of the beetles. Several cigars prepared in this manner were kept until all adults had died, but no signs of feeding or injury to the cigars could be seen. Other beetles were kept in test tubes with small bits of leaf tobacco. In a few tubes the edges of the leaf had been slightly gnawed and fine particles of the leaf were found. Beetles confined in tubes closed with cork stoppers frequently gnaw into the cork for a short distance. No evidence has been secured to show that cigars or tobacco are directly injured by the adult or beetle except when burrowing out after transforming from the pupa stage. Eggs are deposited and the adults apparently live the normal length of time whether food is present or not. At Clarksville, Tenn., a number of experiments were made by Mr. K. B. McKinney and the writer to determine whether the presence of food has any bearing on egg deposition or length of life of the adults. A brief summary of the results obtained in one series of experiments

follows: Number of pairs of beetles under observation, 44; average length of life of males kept without food, 23.1 days; average length of life of males kept with food, 21 days; average length of life of females kept without food, 31.2 days; average length of life of females kept with food, 30.5 days.

Another series of experiments was made to determine the length of life without food at ordinary room temperatures in summer. Twenty-three pairs of beetles were placed in separate tubes directly after emergence. The average length of life was 21 days for the males and 40.4 days for the females. Records from 24 pairs of beetles kept under observation at Clarksville, Tenn., during August and September, 1916, by Messrs. J. E. McMurtrey and E. H. Vance show an average length of life of 17.7 days for males and 21.4 days for females. An average of 30 eggs per female was obtained. The greater number of eggs was deposited between the third and the eighth day after egg-laying began. The period of oviposition ranged from the first until the seventeenth day after mating was observed. A similar experiment during the same period with 18 pairs of beetles kept without food gave the following: Average number of eggs deposited per female, 24; average number of days males lived, 21.2; average number of days females lived, 26.3.

### OVIPOSITION.

Egg-laying usually begins in from 2 to 6 days after emergence. A large proportion of the females kept under observation commenced laying eggs the second and third day after mating. Indoors, where infested material is kept warm and is not subjected to much variation in temperature, the eggs may be found at any time. Humidors for storing cigars and tobacco usually are in steam-heated buildings, and the warmth and moisture conditions foster continuous reproduction throughout the year. Eggs usually are not deposited at temperatures below 70° F. The adults are more active at high temperatures, and eggs are most abundant in tobacco during the warmer period in summer. In the Middle and Northern States, when tobacco is subjected to approximately out-of-door conditions of temperature in unheated buildings, the eggs are laid only during the warmer months of the year. At Richmond, Va., the last eggs were obtained on October 28, 1914, from beetles kept in unheated buildings and the first eggs were obtained on May 2 of the following spring. Under ordinary conditions the eggs are deposited singly, usually in depressions or folds of the food substance. Owing to their small size and secluded location they do not ordinarily attract attention. Even to many who are thoroughly familiar with other stages of the beetle in tobacco the egg is an unfamiliar object.

There is a belief quite common that the eggs of the tobacco beetle are laid on the leaf tobacco in the fields or during the process of curing, and that these eggs do not develop until the tobacco is handled or made up into cigars or other products. This is not the case, as the eggs hatch within a few days after they are deposited and the beetles do not infest tobacco until it is cured. The eggs are laid during both day and night. In cigars, the greater number of eggs is deposited in the open end, the beetles frequently burrowing in the filler to a considerable distance.

At Key West, Fla., large numbers of adults were placed in test tubes containing fresh cigars of the panatela and perfecto shapes. After a few days the cigars were cut in sections, unwrapped, and the location of the eggs noted. Results from 10 cigars containing, in all, 372 eggs were as follows: Panatelas, 220 eggs; on outside, 6 eggs; inside, at end, first inch of cigars, 184 eggs; rest of cigars, 30 eggs. Perfectos, 152 eggs; on outside, 11 eggs; inside first inch of cigars, 129 eggs; rest of cigars, 12 eggs. In this experiment the number of eggs deposited on the outside of the cigars was probably more than normal owing to the large number of beetles in the tubes. In a similar experiment at Richmond, Va., with cigars of various shapes, only 5 per cent of a total of 320 eggs were found on the outside. This experiment was made with boxed cigars. All of the eggs recorded as deposited on the outside of the cigars were between two cigars closely packed, or on the edge of the filler exposed at the open end. In no instance were eggs laid on the wrapper where the surface was smooth. With cigarettes the eggs are deposited within the wrappers, the greater number being found near the end. In plug tobacco eggs were found mostly along the roughened edges of the slices, and between the slices when closely packed. The eggs do not adhere readily to leaf tobacco and are easily dislodged by handling.

### NUMBER OF EGGS LAID, AND PERIOD OF OVIPOSITION.

The number of eggs laid by individual females varies greatly, depending on the vitality of the beetle, on the food obtained while in the larva stage, and on the temperature and moisture conditions during the egg-laying period. The largest number shown by any record obtained thus far is 103. This record, which also shows the rate of egg deposition, is as follows: On April 16, 1915, a pair in copula was placed with leaf tobacco in a tube and kept in an incubator at a constant temperature of 86° F. and a relative humidity of 80 per cent. The first eggs were laid April 17. The daily egg deposition from April 17 to April 25 is as follows: 24, 17, 18, 14, 11, 10, 2, 4, 3; total, 103. The male died April 21 and the female April 28.

In experiments made by the writer at Tampa, Fla., a total of 567 eggs was obtained from 21 females, or an average of 27 eggs each. The longest period of oviposition was 11 days. The largest number of eggs found in any one of 64 females dissected by Mr. S. E. Crumb on August 3, 1911, was 22.

At Clarksville, Tenn., the average number of eggs laid per female during July, August, and September was 32, as shown by 63 separate records. The longest period of oviposition was 21 days. Approximately 66 per cent of the eggs were laid during the first six days after mating was observed. Each pair of beetles was kept in a shell vial containing leaf tobacco.

### INFERTILE EGGS.

Occasionally a female was found to lay infertile eggs, even after mating. No eggs were obtained from unmated females. In one series of experiments, of a total of 182 eggs obtained from 24 different females found in copula, 25 eggs, or 13.7 per cent, were infertile. The eggs were deposited on leaf tobacco and kept at a temperature of about 84° F., the daily variation being about 5°. This infertility probably is much above the average, as hatching in many other lots was almost perfect. The number of infertile eggs in 11 different lots, containing in all 773 eggs, was 30, or approximately 3.8 per cent.

### LENGTH OF DIFFERENT STAGES IN DEVELOPMENT OF INDIVIDUAL BEETLES.

The following records from life-history studies made at Richmond, Va., show the time required for each period of development of different beetles from the egg to the adult.

TABLE III.—*Length of different stages in development of individual tobacco beetles (Lasioderma serricorne). Richmond, Va., 1914.*

| Record No. | Egg laid— | Hatched— | Larva formed cell— | Larva pupated— | Adult appeared— | Adult left cell— |
|---|---|---|---|---|---|---|
| 1 | July 1 | July 8 | Aug. 17 | Aug. 22 | Aug. 29 | Sept. 6 |
| 2 | ...do... | ...do... | Aug. 19 | Aug. 23 | Sept. 1 | Sept. 5 |
| 3 | July 5 | July 12 | Aug. 22 | Aug. 28 | Sept. 4 | Sept. 9 |
| 4 | June 1 | June 7 | July 18 | July 22 | July 29 | Aug. 2 |
| 5 | June 18 | June 25 | July 30 | Aug. 3 | Aug. 9 | Aug. 16 |

| Record No. | Mated— | Eggs laid— | Food. | Egg to beetle. | Egg to egg. |
|---|---|---|---|---|---|
| | | | | *Days.* | *Days.* |
| 1 | Sept. 9 | Sept. 11 | Tobacco | 59 | 72 |
| 2 | Sept. 7 | Sept. 10 | ...do... | 62 | 71 |
| 3 | Sept. 10 | Sept. 17 | ...do... | 61 | 74 |
| 4 | Aug. 6 | Aug. 9 | ...do... | 58 | 69 |
| 5 | Aug. 21 | Aug. 24 | ...do... | 52 | 67 |

### PHOTOTROPISM.

Adults of the tobacco beetle are accustomed to darkness or semi-darkness. Up to a certain degree of intensity they respond positively toward light, but they are negatively phototropic if the light is too intense. Observations made in tobacco warehouses and on beetles in specially constructed cages at the laboratory showed that they avoid intense sunlight, but toward sunset, or when the light intensity is lowered, they move toward the source of light.

### REACTION TOWARD COLORED LIGHT.

Laboratory experiments made with apparatus which transmitted light through color screens or ray filters which made it practically monochromatic showed conclusively that the tobacco beetle, in common with other insects, reacts most strongly to colors of shortest wave length. The movement toward blue or blue-violet is most pronounced, and the movement toward red least of all. When a series of traps was operated with the light transmitted through color screens placed in regular order from red to violet the number of beetles attracted, in the majority of instances, increased in fairly regular order from red to violet. Experiments made with electric lights showed that the beetles were attracted toward a bulb of clear glass transmitting light rich in rays of short wave length, and scarcely at all toward a bulb of red glass, which transmitted rays of long wave length giving light at the lower or red end of the spectrum.

The adults, in common with other insects reacting negatively toward intense sunlight, are only slightly sensitive to light at the lower end of the spectrum, and rays of longer wave length, limited to red and orange, seem to act on them in much the same manner as darkness. Adults exposed to bright sunlight under color screens of red and blue were observed to collect under the red screen almost as readily as they did when an opaque screen was used in place of the red, although the apparent intensity of light under the two screens was the same. This shows a reaction directly opposite to that observed when the beetles, in darkness, are exposed to lights of low intensity.

### EFFECT OF TEMPERATURE ON ACTIVITY OF ADULTS.

A series of laboratory experiments was conducted to ascertain the effect of ascending and descending temperatures on the activity of adults. Beetles were confined in the lower part of a long glass tube 20 millimeters in diameter. A thermometer was passed through an opening in the cork and the tube lowered into an inverted bell jar filled with water. A support was arranged in such a manner that the bell jar could be lowered into melting ice, or into a basin of water which

could be heated gradually by an alcohol lamp underneath. By this means the temperature of the tube containing the beetles could be gradually raised or lowered as desired. In experiments with descending temperatures the beetles were taken from a lot reared in confinement and were kept at a constant temperature of 81° F. Those used in tests of rising temperatures were kept for a short time at 32° and were inactive when the experiment was commenced. Ten beetles were used in each test, a different lot being used each time. With increasing temperatures the beetles begin activity at temperatures between 48° and 75° F., one-half being active at 60° and 75 per cent at 64° F. With decreasing temperatures the beetles become inactive between 62° and 48° F., one-half being inactive at 56° and 75 per cent inactive at 55° F. In infested tobacco warehouses the adults are seldom found active at temperatures below 65° F. Activity increases as the temperature becomes higher. At temperatures between 117° and 120° F. all activity ceases, and temperatures above 117° F., if continued, result in death.

## SEASONAL HISTORY.

### SEASONAL ABUNDANCE AND NUMBER OF GENERATIONS.

Since the tobacco beetle is an indoor or stored-product insect, the terms "brood" and "generation" can hardly be applied in the sense that they are used in dealing with field insects, as the seasonal appearance and number of generations of such insects depend largely upon the variations in climatic conditions. In food substances maintained at constant warm temperatures adults may be found at any season of the year, and the wide variations in the time required for development under the same breeding conditions produce an overlapping of generations. Under ordinary conditions in warehouses there are, however, well-marked periods during which the adults are most abundant. At Key West and Tampa, Fla., most cigar manufacturers state that the adults are most abundant during the months of February and March, and again in August and September. At these places, however, the abundance of adults at any time may depend more upon the time the heaviest shipments of cigar tobacco from Cuba are received than upon local climatic conditions.

In the latitudes of Virginia and Tennessee there seems to be a period of greater abundance with the advent of the first warm weather in June, and again a marked increase occurs during September.

In tobacco warehouses at Clarksville, Tenn., adults usually begin to appear about May 1, and after November 1 comparatively few adults can be found. In unheated buildings three generations are possible between May 1 and November 1.

In the laboratory at Clarksville, Tenn., beetles were kept under observation continuously by Mr. S. E. Crumb during 1910–11. The rearing material was kept in a room heated only during the day during winter. Larvæ which constructed pupal cells in November, 1910, became adults May 18, 1911. These beetles deposited eggs about May 31, from which adults were obtained about July 29. These beetles deposited eggs August 13, from which adults were obtained on September 28. Eggs were obtained from these adults October 5. Larvæ from this lot of eggs constructed cells in which they passed the winter of 1911–12. This gives for the locality three distinct generations, emerging in the adult stage in May, July, and September. In localities farther south from three to six generations may occur, since under laboratory conditions at normal summer temperatures the entire life cycle was found to average 60 days.

At Richmond, Va., it was determined that three generations may occur under warehouse conditions. On October 14, 1913, eggs were placed in tobacco, and larvæ were found in cells in a dormant condition during December, which transformed the following spring. Adults collected from the lot May 5, 1914, deposited eggs on May 6–7. Adults reared from these eggs were obtained July 22, and eggs were laid about July 25. From these eggs adults were again obtained about October 2. Eggs deposited by beetles from this lot hatched October 18, the larvæ becoming dormant during the latter part of November. This shows that for this locality there are three complete life cycles, the adults appearing in May, July, and October, and that from the adults which emerge earliest there is a possibility of a fourth generation reaching the adult stage before winter.

In the Middle and Northern States, in warehouses and tobacco factories, a sudden appearance of large numbers of adults in spring or early summer is frequently observed. The greater number of larvæ which survive the winter complete their transformation and emerge in the adult stage with the advent of warm weather.

## INSECTS LIKELY TO BE MISTAKEN FOR THE TOBACCO BEETLE.

Belief still prevails in many sections that the tobacco beetle is found on growing tobacco and that it continues to feed upon the tobacco after it has been cured. This impression is due perhaps to its slight resemblance to a smaller and very common insect, the tobacco flea-beetle (*Epitrix parvula* Fabricius) (fig. 8), which is abundant on growing tobacco in the field and in tobacco plant beds. Contrary to this belief the tobacco beetle (*Lasioderma serricorne*) does not attack growing tobacco and is not present in tobacco fields. It is not a field insect, but feeds and lives in dried substances, its more common food being cured tobacco. The habit of the tobacco flea-beetle of hopping when disturbed, its occurrence on growing tobacco, its smaller size,

and its general appearance will serve readily to distinguish it from the tobacco beetle. Several species of insects which occasionally are found living or feeding in dried tobacco are likely to be mistaken for the tobacco beetle. These are enumerated below.

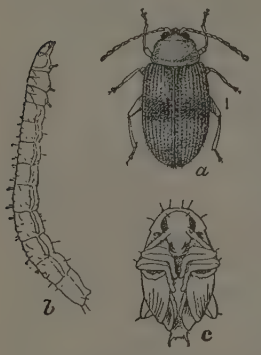
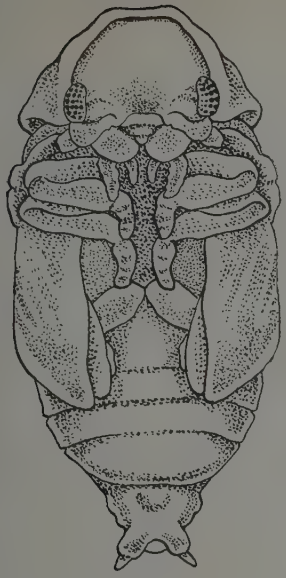



FIG. 8.—The tobacco flea-beetle (*Epitrix parvula*): *a*, Adult; *b*, larva, side view; *c*, pupa, from below. Enlarged. (Chittenden.)

A reddish-brown beetle (*Thanerocleru girodi* Chevrolat), considerably larger than the tobacco beetle, often may be found in tobacco or in boxes of cigars. This species feeds on the different stages of the tobacco beetle. The adult, larva, and pupa stages are shown in Plate II, figure 3; Plate III, figure 5; and Plate IV. This insect is more fully discussed in the section dealing with the parasitic and predacious enemies of the tobacco beetle.

The larger tobacco beetle (*Catorama tabaci* Guérin) (Pl. II, fig. 1; Pl. III, figs. 2, 4; text figs. 9 and 10) attacks cured tobacco and tobacco seed in much the same manner as does the common tobacco or "cigarette" beetle (*Lasioderma serricorne*) and its larger size makes it still more destructive than is the common species. Cigar tobacco injured by *Catorama tabaci* is shown in figure 6. So far as known this species has been reported only from three localities in the United States. It was found in tobacco in this country for the first time in 1912. One of the leading cigar companies at Key West, Fla., reported the insect to the Bureau of Entomology and sent specimens collected in a shipment of cigar tobacco from Habana, Cuba. At about the same time a similar report accompanied by specimens was received from a cigar company located in Philadelphia, the beetles having been found also in a shipment of Habana tobacco. In the following year specimens of the Catorama were taken by Mr. A. C. Morgan of the Bureau of Entomology in bales of Habana tobacco which were being removed from a bonded warehouse at Key West, Fla., and also by the writer, in a bonded warehouse in Tampa, Fla. The records obtained indicate that the insect is native to Cuba. It was introduced into Paris, France, from Cuba and was first described by Guérin-Ménéville (11) from the Paris importations in 1850, having been found in Habana cigars.

FIG. 9.—The larger tobacco beetle (*Catorama tabaci*): Antenna of adult. Greatly enlarged.



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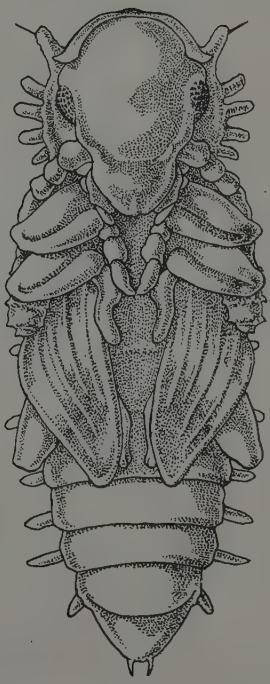

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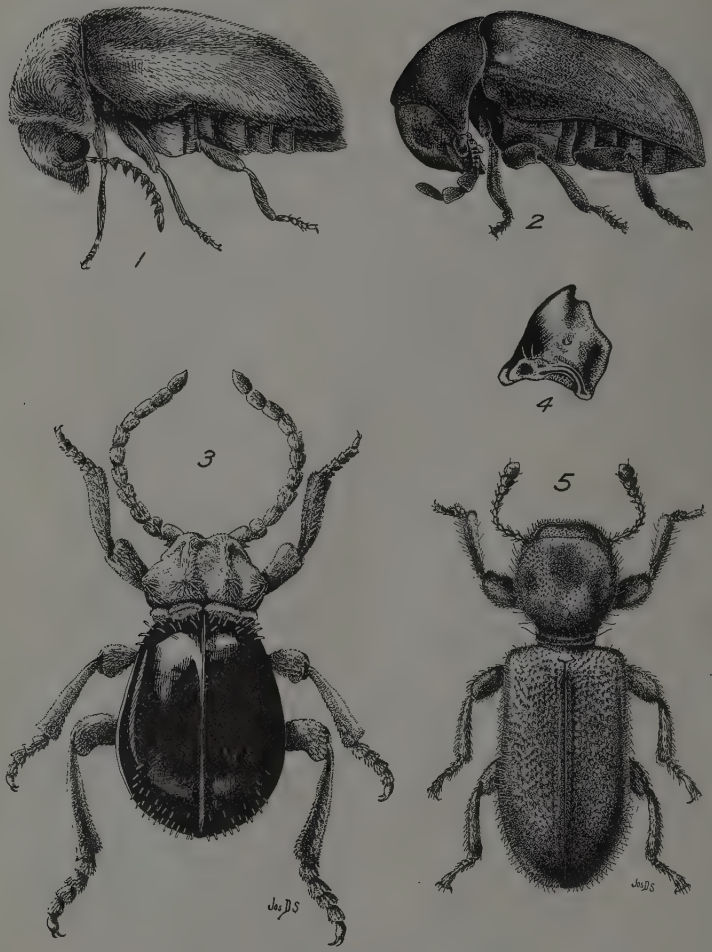
PUPÆ OF BEETLES THAT FREQUENT CURED TOBACCO.

FIG. 1.—The larger tobacco beetle (*Catorama tabaci*). FIG. 2.—The tobacco beetle (*Lasioderma serricorne*). FIG. 3.—*Thaneroclerus girodi*, a predatory enemy of the tobacco beetle. FIG. 4.—Saw-toothed grain beetle (*Silvanus surinamensis*). (Drawings by Joseph D. Smith.)




## BEETLES THAT FREQUENT CURED TOBACCO.

FIG. 1.—The tobacco beetle (*Lasioderma serricorne*). FIG. 2.—The larger tobacco beetle (*Catorama tabaci*). FIG. 3.—*Mezium americanum*. FIG. 4. *Catorama tabaci*: Left mandible of larva, dorsal view. FIG. 5.—*Thanerocleras girodi*, a predacious enemy of the tobacco beetle (*Lasioderma serricorne*). (Drawings by Joseph D. Smith.)

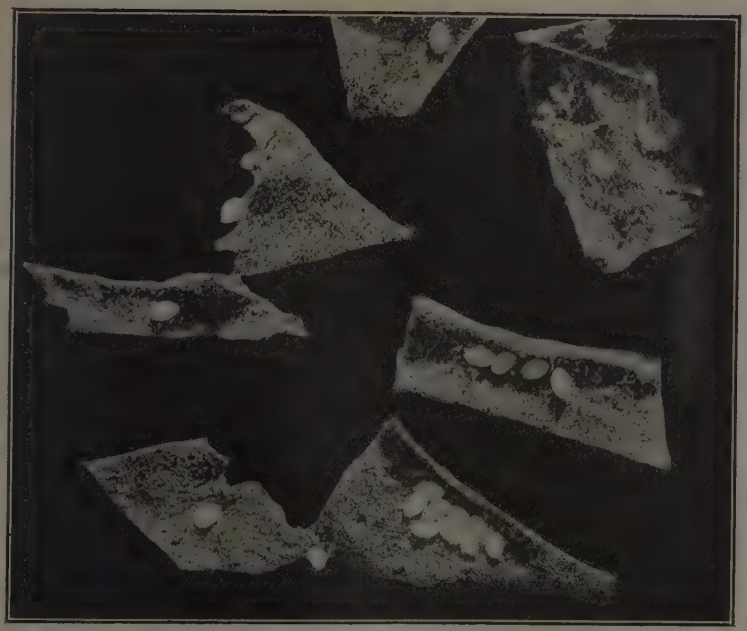


FIG. 10.—Eggs (enlarged) of the larger tobacco beetle (*Catorama tabaci*) on leaf tobacco.

*Silvanus surinamensis* Linnaeus and *Cathartus advena* Waltl are occasionally extremely abundant in tobacco warehouses, and the first-named species has been found to feed to a slight extent on tobacco and tobacco seed. The pupa of *S. surinamensis* is shown in Plate II, figure 4.

Jones (77) states that in the Philippines a species of Bostrychidae and the shot-hole borer of bamboo (*Dinoderus brevis* Horn) are abundant and often are mistaken for the tobacco beetle. Like other insects often found in tobacco, their occurrence, however, is purely accidental. Three other species of beetles have been recorded (43) as injuring cured and manufactured tobacco. These are the drugstore beetle (*Sitodrepa panicea* Linnaeus), the rice weevil (*Calandra oryza* Linnaeus), and the leather beetle (*Dermestes vulpinus* Fabricius). The first of these insects is similar in general appearance to the tobacco beetle and might be mistaken for it, but the form of antenna (fig. 11) serves to distinguish it from the tobacco beetle (fig. 7).

FIG. 11.—The drug-store beetle (*Sitodrepa panicea*): Antenna of adult. Greatly enlarged.

In addition to the insects already mentioned the following species have been found frequenting cured tobacco: *Trogoderma tarsale* Melsheimer, *Attagenus piceus* Olivier, *Tenebrioides mauritanica* Linnaeus, *Mezium americanum* Laporte. *Catorama impressifrons* Fall and *Attagenus piceus* Olivier have been recorded by Morgan (70) as infesting tobacco seed. *Mezium americanum* Laporte (Pl. III, fig. 3) has been found breeding in tobacco seed by Mr. S. E. Crumb of the Bureau of Entomology.

## NATURAL CONTROL.

Numerous natural agencies are concerned in the control of the tobacco beetle. These forces, singly or combined, serve to keep the insect in check.

### CLIMATIC CONTROL.

In the temperate zones, at least, the most important factor in holding the beetle in check is the cold of winter. Under ordinary conditions in cool climates their activities are confined to about one-half of the year. A comparatively small proportion of the insects survive the winter when exposed to even moderate cold if it is long continued, or to sudden abnormal changes of temperature. Severe freezing at temperatures lower than 10° F., if continued even for a short time, will result in extermination. At different times in order to determine the effect of exposure to variations of temperature in unheated buildings, heavily infested cans of smoking tobacco were wrapped in paper and kept over winter in various localities. The records obtained are as follows:

#### AT APPOMATOX, VA., WINTER OF 1910–11.

About 10 pounds of pressed plug and granulated smoking tobacco heavily infested were placed in original packages, in a large pasteboard box, wrapped with paper, and kept in an unheated room. A self-registering thermometer in the package showed that the lowest temperature reached was 11° F. Practically out-of-door conditions were experienced from December, 1910, until April, 1911. The beetles were exterminated. The tobacco was kept for several months but did not show signs of reinfestation.

#### AT RICHMOND, VA., WINTER OF 1913–14.

Two 5-pound packages of infested smoking tobacco were wrapped in paper. One package was placed in an unheated cellar, the other in a partly open building giving approximately out-of-door temperature variations. Both lots of tobacco were heavily infested. The

exposure extended from November, 1913, until March, 1914. A self-registering thermometer in the open building showed the lowest temperature to be 12° F., and this temperature was reached several times during the winter. The lowest point reached in the cellar was not determined, but the protection afforded gave somewhat higher temperatures than obtained in the open building. On examination in March a very few live larvæ were found in the tobacco kept in the cellar. The tobacco in the open building was completely sterilized. The package was sealed and kept under observation until June, 1914, but no live stages of the beetles were found.

AT OAK HARBOR, OHIO, WINTER OF 1914–15.

A package prepared at Richmond, Va., contained about 5 pounds of heavily infested smoking tobacco, part pressed or sliced plug and the rest granulated, and a package of infested cigars and cigarettes. About 1,000 eggs of the tobacco beetle had been placed in the smoking tobacco November 1, 1914. This was mailed on November 14 to Oak Harbor, Ohio, where it was placed in an unheated building on November 17. It was examined June 10, 1915. No live stages of the beetle were found. The lowest temperature registered in the building was 10° F.

AT CLARKSVILLE, TENN., WINTER OF 1915–16.

About 10 pounds of smoking tobacco wrapped in paper were kept over winter in an unheated room in the laboratory. The tobacco contained all stages of the beetle. On November 1, 1915, about 1,000 eggs of the beetle were placed in the tobacco. These eggs hatched about November 10. No record was secured of the lowest temperature in the room. The lowest record out of doors was 5° F. The tobacco was examined during April, 1916. No live stages of the beetle were found. Although the tobacco was kept under observation for several months no signs of infestation were observed.

Evidence of the effect of freezing on the tobacco beetle has been observed on numerous occasions and it is not uncommon to find leaf tobacco or other food substances which have been exposed to low temperatures completely free from the beetle although its condition showed that it had been heavily infested previously. It has been the experience of those familiar with the tobacco industry that beetles always become more abundant and destructive after a mild winter.

DRYING OUT OF FOOD SUBSTANCES.

The tobacco beetle thrives best in tobacco that is protected from rapid evaporation and when the humidity is high. If the tobacco remains very dry for a considerable length of time the rate of multi-

plication is largely checked. In all cases observed in rearing experiments, the insects failed to develop properly if the food substance became too dry or if the larvæ or pupæ were not protected from excessive evaporation.

#### MOLD IN FOOD SUBSTANCES.

The growth of mold in the food substance usually results in the complete extermination of the beetle. This has been observed in many instances. It is often owing to this fact that infestation from damaged or worthless products does not extend to uninfested products near by.

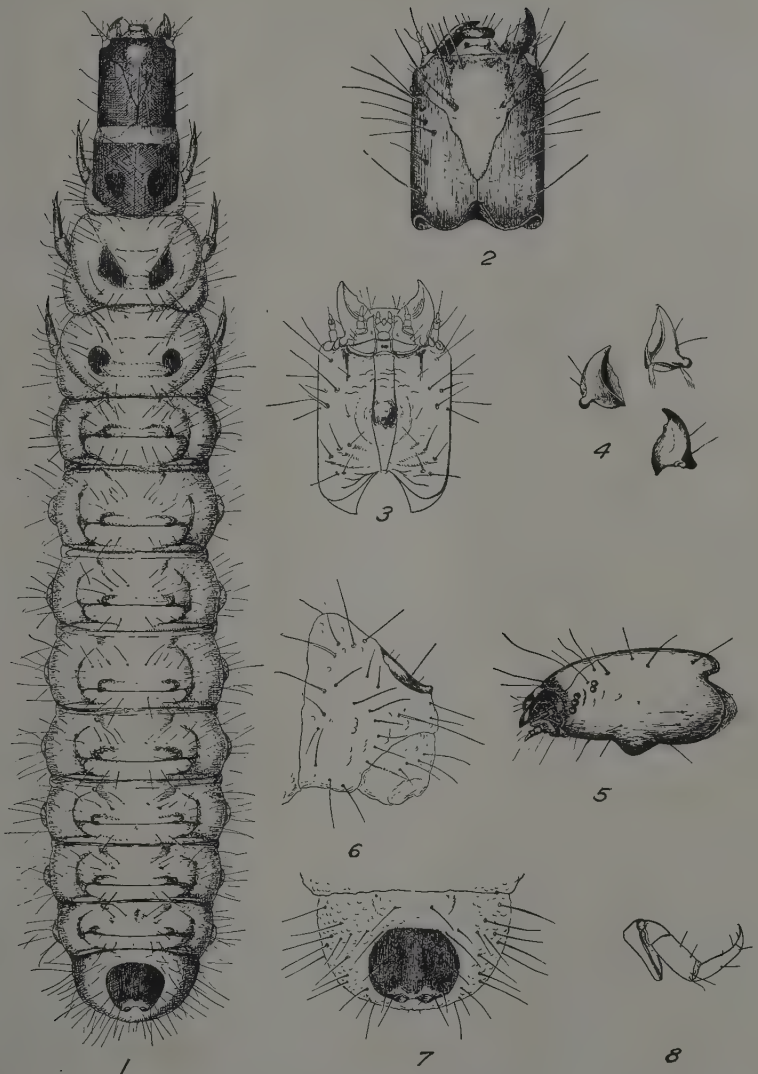
#### INSECT ENEMIES.

Several species of insects have been found to destroy the tobacco beetle and some of these appear to be widely distributed. While both predatory and parasitic insects are important factors in the repression of the tobacco beetle, the insect still is able to maintain itself successfully in all localities where it has become established.

#### Predacious Insects.

##### THANEROCLERUS GIRODI Chevrolat.

Among predatory enemies of the tobacco beetle the most important, so far as is known, is the clerid beetle *Thaneroclerus girodi* Chevrolat (Pl. II, fig. 3; Pl. III, fig. 5; Pl. IV). This beetle was found in unusually large numbers at Key West, Fla., and is a very important factor at that cigar-manufacturing center in keeping the tobacco beetle in check. It was first found in the United States by Dr. W. D. Hunter and Mr. A. C. Morgan, of the Bureau of Entomology, at Key West, Fla., in April, 1912 (78). Specimens of the beetle were determined by Mr. E. A. Schwarz, of the Bureau of Entomology. The insect has since been found by the writer to be more or less common, but much less abundant, at Tampa, St. Petersburg, Jacksonville, and Quincy, Fla., and was found in tobacco stored in a tobacco barn at Tallahassee, Fla., in 1914 by Mr. J. R. Watson, State entomologist of Florida. Specimens were also located at Richmond, Va., in a package of smoking tobacco infested with the tobacco beetle, which had been returned to the manufacturers from Galveston, Tex. Mr. John Wardlow, of Key West, Fla., stated that he had observed the beetle frequently in the bales of cigar tobacco imported from Habana, Cuba. Among Cuban cigar makers the insect seems to be well known. They state that it is common in cigar factories in Habana, where it is called the "bicho grande" or "big bug" to distinguish it from the smaller species, the tobacco beetle (*Lasioderma serricorne*), upon which it




LARVA OF THANEROCLERUS GIRODI.

FIG. 1.—Dorsal view of body. FIG. 2.—Dorsal view of head. FIG. 3.—Ventral view of head. FIG 4.—Views of mandible. FIG. 5.—Side view of head. FIG. 6.—Lateral view of ninth and tenth abdominal segments. FIG. 7.—Dorsal view of ninth abdominal segment. FIG. 8.—Leg. (Drawings by Adam G. Böving.)

feeds. Jones (77) has described the habits of an undetermined clerid beetle which, he states, feeds in both the larva and adult stages upon the tobacco beetle in the Philippines. The drawings of the different stages of the clerid, given by Jones, show it to be either *Thaneroclerus girodi* or a very closely related species. Wolcott (72) records its presence in the United States.

The insect is new to the fauna of the United States and there is, in addition to the foregoing records, only a single reference to it in entomological literature, this being the original description by Chevrolate (18).

### THE ADULT.

The adult (Pl. III, fig. 5) is a reddish-brown beetle about 6 mm. in length. The wing covers and thorax are pitted and somewhat pubescent. The indentations are smaller and somewhat more regular on the thorax than on the elytra. The original description by Chevrolat (18) is as follows:

THANEROCLERUS GIRODI.—Long. 6 mill.; lat. 2–1/3 mill. Elongatus, sanguineus, pilosus creberrime punctulatus; capite magno convexo, antice semicircuiter emarginato et crassiusculo; mandibulis nigris; antennis elongatis, art. 2 primis funiculi a equalibus modice elongatis, clava 3 articulata; prothorace minute et crebre punctulato, medio depresso et anguste sulcato; scutello rotunde transverso, longitudine sulcato; elytris in medio depressis; pedibus pallidioribus.

The following descriptions of the egg and pupa stages were prepared by Mr. S. E. Crumb from specimens collected at Quincy, Fla., in 1913. Dr. Adam G. Böving has drawn up the technical description of the larva.

### THE EGG.

Egg elliptical oval, faintly yellowish, 1.2 mm. long and 0.38 mm. broad at middle, membranous, without apparent sculpture, bearing on one side about one-third from the larger end two small, short, distant bristles.

### THE LARVA.[1]

(Pl. IV.)

#### GENERAL CHARACTERS.

Ventral side of epicranium continued horizontally behind posterior end of hypostoma and its tentorial pits; gula a rectangular plate between ventral margins of epicranium; occiput vertical. Mouthparts prognathous; labrum and clypeus present; antenna three-jointed; mandible without molar part, with simple apex and deep groove along cutting edge; ventral mouthparts not retracted; maxillary cardo as large as stipes, only posterior half chitinized; maxillary palpiger present, carrying a three-jointed palp; lacinia bilobed, extending from distal end of stipes; submentum well defined, in front of gular plate; no maxillary articulating area; mentum freely projecting; stipes labialis with well developed palpiger, two-jointed palp, and ligula; buccal cavity with a pair of small, widely separated, bidentate, hypopharyngeal chitinizations and a pair of flat, rounded, pharyngeal plates. Tentorium represented by a

[1] The descriptions of the larva, with figures (Pl. IV), are by Dr. Adam G. Böving.

pair of thin membranous rods, attached near antennal ring; no hypopharyngeal bracon. Body orthosomatic, elongate, fleshy. Legs five-jointed, with clawlike tarsal joints, no claws; thoracic prehypopleural and posthypopleural parts present and chitinized. Prothorax with large subsellate tergal shield; presternites rounded, paired; prebasisternum and basisternum covered by an unpaired, median, longitudinal, lanceolate chitinization; no sternellum; poststernellum well developed. Mesothorax and metathorax with large, poorly defined prescutum; on each side of scuto-scutellar region a small, rounded chitinization, larger on mesothorax than on metathorax; no median epipleural lobe; large triangular postepipleural arm; preepipleural arm united with the presternite into a fleshy, subtriangular spiracle-bearing region reaching ventrally the spina of the prothoracic poststernellum; no definite sternellum; poststernellum present on mesothorax, absent on metathorax. Abdomen with ten segments; prescutal area faintly indicated; dorsal parts of scutum and scutellum on several segments developed as feeble ampullatory lobes; postscutellum narrow, bandlike; epipleurum well developed with preepipleural and postepipleural arms and a median epipleural lobe; ventral side with parasternum anteriorly limited by a straight line, in front of which there is no longitudinal muscle impression; ninth abdominal segment with a dorsal chitinous plate; tenth abdominal segment fleshy, wart-shaped, with five small lobes encircling the anus. Spiracles annuliform-bifore; the developed thoracic spiracles plainly mesothoracic; the rudimentary thoracic spiracle metathoracic; eighth abdominal spiracles present.

GENERIC AND SPECIFIC CHARACTERS.

Head elongate, with parallel sides, frons not reaching the occipital foramen; epicranial suture present; ocelli five, three in anterior, two in a posterior vertical line; gular plate with a large median, unpaired projection; cutting edge of mandible slightly sinuate; prothoracic shield as wide as head. Cerci rudimentary.

LARVAL INSTARS.

Last-instar larva 7 mm. long; body enlarging slightly posteriorly, pink, set with long, weak, pale yellowish-brown hairs; chitinous parts dark fuscous; head approximately 0.7 mm. broad and about twice as long; shield of ninth segment transversely oval.

THE PUPA.

(Pl. II, fig. 3.)

Pupa pink to reddish, about 5 mm. long and 1.5 mm. broad; head beneath prothorax, prothorax broadly oval dorsally, eight tubercles on margin of anterior half, the most anterior pair forming a trapezoidal figure with two bristles posterior to them. Behind these two bristles and forming an arc with the adjacent marginal bristles are three equidistant transverse rows of bristles and on the posterior margin is a median group of four. Tubercles subconical and set with long, weak, yellowish-brown bristles. Antennal joints apically bearing large angular tubercles. Tip of abdomen bearing dorso-laterally a pair of curved divergent horns and apically a pair of conical fleshy appendages each apparently composed of three segments.

NOTES ON HABITS AND LIFE HISTORY.

To the description given by Chevrolat a brief note is added, of which the following is a translation:

This insect, peculiar to Cuba, has been found by Girod in cases of injured tobacco (injured presumably by the cigarette beetle) and was given tc me by M. Ant. Grouvelle. It is likely to be predacious upon the larvæ and perfect insects of the genus Catorama.

As the tobacco beetle, *Lasioderma serricorne*, was formerly included in the genus Catorama, the surmise made by Chevrolat concerning the food habits of the clerid has been found correct. Studies of the life history of the insect were made by the writer at Key West, Fla., in 1912. At temperatures varying from 80° to 90° F. the period of incubation was found to average about nine days. The eggs were laid singly as a rule, but sometimes were found in groups of two and three. Eggs usually were found in the burrows in cigars formed by the tobacco beetle. The largest number secured from a single female was 18 eggs. Pupation required from five to eight days, the average pupal period being about seven days. Pupation may take place in any secluded locality. The greater number of pupæ were found in holes in infested cigars. The larval periods as observed from three specimens were 42, 51, and 62 days respectively. From the development of a number of partly grown larvæ kept for about 30 days the larval period is thought to correspond closely to that of larvæ of its host, the tobacco beetle, the exact length of the period varying with temperature conditions and the abundance of food. Adults kept in tubes with cigars did not bore into the wrapper, but holes already made by the tobacco beetle were considerably enlarged. Adults of *Thaneroclerus girodi* feed on the larva, pupa, and adult stages and on dead adults of *Lasioderma serricorne*, as well as on dead adults of their own species. The larvæ of the predacious beetle feed on eggs, larvæ, and pupæ of Lasioderma. Both larvæ and adults are cannibalistic when deprived of other food, this habit enabling the species to survive for a considerable length of time after all the Lasioderma obtainable have been devoured. When other food can not be obtained, these predacious larvæ feed upon the eggs, larvæ, and pupæ, and the predacious adults on the eggs, larvæ, and pupæ of their own species. The abundance of these beetles at times doubtless accounts for the complete disappearance of the tobacco beetle in boxes of damaged cigars, so often noticed in certain cigar factories.

### Parasitic Insects.

Several species of hymenopterous parasites of the tobacco beetle have been recorded. Some of these are extremely abundant in infested leaf tobacco in warehouses and are without doubt important in natural control.

*Aplestomorpha pratti* Crawford is one of the more common species and has been found in various localities from Richmond, Va., southward to Key West, Fla.

*Aplestomorpha vandinei* Tucker was found abundant in a tobacco warehouse at Clarksville, Tenn. Specimens of this parasite were collected by Mr. J. U. Gilmore, of the Bureau of Entomology, and placed with larvæ of the tobacco beetle, from which specimens of the parasite were reared later. The egg and also the larval period was found to be six days, and the pupal period about 7 days. The larvæ were observed to feed externally on both larva and pupa stages of the tobacco beetle. Specimens were determined by Mr. A. A. Girault, of the Bureau of Entomology. Fullaway (79) records an undetermined species of Pteromalus reared from the tobacco beetle in Hawaii. Jones (77), in the Philippines, describes and figures *Norbanus* sp., which attacks larvæ and pupæ of the tobacco beetle while in the pupal cells.

*Catolaccus anthonomi* Ashmead has been recorded as a parasite of *Lasioderma serricorne* (43), but Mr. J. C. Crawford considers this an error. The original specimen can not be found.

### Other Enemies.

Various species of mites are found frequently in tobacco, and some of these have been found to feed on eggs of the tobacco beetle. At

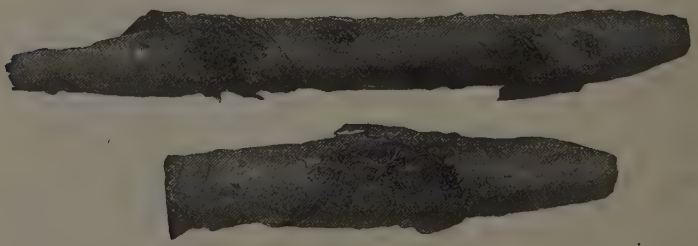


FIG. 12.—Cigars showing work of a jointed spider (Order Solpugida). Holes torn by the solpugid in order to reach larvæ or pupæ of the tobacco beetle (*Lasioderma serricorne*) within the cigar.

Tampa, Fla., considerable difficulty was experienced in keeping eggs used in experimental work from being destroyed by the mites. Specimens of these were examined by Mr. Nathan Banks, then of the Bureau of Entomology, and found to be a species of Cheyletus. The larva form of a mite belonging to this genus was observed to insert its beak into the eggs of the tobacco beetle, remaining in this position for some time, and leaving the eggs more or less collapsed. The adult females of this species were observed to stand guard over their own eggs, which were deposited in clusters and kept underneath the female. The clusters contained from 20 to 30 eggs. A mite belonging to the family Eupodidae, genus Rhagidia, has been

recorded as attacking the tobacco beetle in all stages except the adult, in the Philippines (77). It is not uncommon to find mites of the genus Tyroglyphus feeding on dead larvæ and pupæ of the tobacco beetle. It is probable that live stages of the tobacco beetle are not attacked and that the mites present in these instances are merely acting as scavengers.

At Key West, Fla., a species of jointed spider of the order Solpugida and a small arachnid belonging to the order Pseudoscorpiones were found by the writer to destroy larvæ of the tobacco beetle. While these arachnids may destroy a considerable number of beetles and do no particular damage to the leaf tobacco, the work of the solpugid in cigars would hardly be considered beneficial, as the cigars are badly torn by the spider in its efforts to dig out the larvæ. The nature of this injury is shown in figure 12.

## REMEDIAL MEASURES.

### COLD STORAGE.

A readily available and effective means of treating infested tobacco is found in the modern cold-storage plant. This treatment has been used to a considerable extent, but usually the temperatures in operation have the effect of suspending insect activity rather than of causing death. The beetles become inactive at temperatures below 65° F., and the storage of infested materials at temperatures between 32° and 65° F. prevents further damage as long as the material is held in storage. When lower temperatures are available a more satisfactory and effective method, although somewhat more expensive, is to subject the tobacco for a week or more to the lowest temperature that can be obtained. Cigars or manufactured tobacco should either be removed from cold storage when the air is dry, to prevent "sweating," or the temperature should be raised gradually before removal. Air-tight receptacles for holding the cigars or tobacco and an atmosphere as dry as can possibly be secured are desirable when the cold-storage method is used. If the material is removed when the air is damp the condensation of moisture may cause the boxes to be discolored or develop mold in the tobacco or cigars.

A large number of cigars in boxes, placed in cold storage, were kept under observation by the writer. These cigars were not put in sealed containers but were merely placed in piles on the floor of the cold-storage room. They were removed when the air outside was dry and cool, put under presses in a dry room, and left for a time to prevent warping of the boxes. The treatment proved thoroughly effective in sterilizing the cigars, and the manufacturer reported that no injury was apparent. Different lots were kept at a temperature of about 12° F. for from one to four weeks.

Although there are certain objections to the method, such as loosening the wrappers of fine cigars by sudden changes in temperature, danger of injury from "sweating" on removal from cold storage, and injury to quality from too rapid aging, it has certain advantages and in some cases may be found more desirable than other methods of treatment. When care is taken to prevent "sweating," it is evident that the exposure of manufactured or leaf tobacco in cold storage is not more apt to produce injury than would be the exposure of the same material to low temperatures during the winter.

In determining the effect of cold-storage temperatures upon different stages of the tobacco beetle, experiments were conducted during 1913 and 1914 at Richmond, Va. The temperatures available for most of the experiments ranged from 12° to 16° F. At the laboratory an automatically regulated incubator heated by an electric current was used in rearing the beetles for experimental work and for holding the material used in the tests after it had been removed from the cold-storage room. By this means the proper temperature and degree of moisture favorable for the development of different stages of the beetle could be kept constant. A large quantity of infested manufactured tobacco of different kinds was secured from dealers and manufacturers. In many of the experiments the exposure to cold was made with the tobacco in original packages. Tobacco found slightly infested was kept in the incubator and eggs or other stages of the beetle placed in it until the degree of infestation desired for the experiments was obtained. Experiments were made with eggs on the tobacco or cigars on which they had been deposited, and also, for convenience in making examinations, with the eggs in glass-covered cells on microscope slides.

The results of some of the experiments made by the writer during 1913, and by Mr. S. E. Crumb and the writer during 1914, are given in Table IV.

TABLE IV.—*Effect of cold storage on the tobacco beetle (Lasioderma serricorne). Experiments at Richmond, Va., 1913–14.*

| Temperature. | | Humidity (relative). | | Exposure. | | Stages alive. | | | Stages dead. | | | Success of Experiment. | Material used. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Minimum. | Maximum. | Minimum. | Maximum. | Days. | Hours. | Adults. | Pupæ. | Larvæ. | Adults. | Pupæ. | Larvæ. | | |
| ° *F.* | ° *F.* | *Per cent* | *Per cent* | | | | | | | | | | |
| 11 | 12 | ..... | ..... | 4 | ..... | ..... | 0 | 0 | ..... | All. | All. | Completely effective..... | Sliced plug smoking tobacco. |
| 11 | 12 | 86 | 86 | 5 | ..... | 0 | 0 | 0 | All. | All. | All. | .....do..... | 1 box smoking tobacco. |
| 14 | 16 | 87 | 89 | 4 | ..... | 0 | 0 | 0 | All. | All. | All. | .....do..... | 4 boxes granulated smoking tobacco. |
| 14 | 16 | 84 | 86 | 5 | ..... | 0 | 0 | 0 | All. | All. | All. | .....do..... | Sliced plug smoking tobacco. |
| 14 | 14 | 89 | 89 | ..... | 3.16 | 4 | ..... | 23 | ..... | 10 | 11 | Partially effective..... | Cut-plug smoking tobacco heavily infested. Exposure made in original boxes. Tobacco undisturbed. Examined two days after exposure. |
| 14 | 14 | 86 | 86 | ..... | 10 | ..... | × | × | ..... | × | × | .....do..... | 1-pound can badly infested smoking tobacco. |
| 14 | 16 | 87 | 89 | 1 | ..... | 0 | 0 | Few. | × | × | × | Partially effective; eggs shrunken. | 1 box granulated smoking tobacco. 20 eggs in glass cell placed within the tobacco. |
| 14 | 16 | 87 | 89 | 1 | ..... | ..... | ..... | 15 | ..... | ..... | 60 | Partially effective..... | 1 box sliced plug smoking tobacco. |
| 14 | 16 | 87 | 89 | 2 | ..... | 0 | 0 | 3 | 12 | 11 | 18 | Partially effective; eggs shrunken. | 1 box sliced plug smoking tobacco. Eggs on leaf tobacco placed in same box. |
| 15 | 16 | 89 | 89 | ..... | 21 | ..... | ..... | × | ..... | ..... | × | Partially effective..... | Badly infested sliced plug smoking tobacco in original packages. Examined 5 days after exposure. |
| 16 | 16 | ..... | ..... | 4 | ..... | 0 | 0 | 3 | × | × | × | .....do..... | 5-pound lot granulated smoking tobacco wrapped in paper. |
| 16 | 16 | 86 | 86 | ..... | 23 | ..... | ..... | Few. | ..... | ..... | × | .....do..... | Infested smoking tobacco (pressed) in sealed glass jars. |
| 16 | 17 | ..... | ..... | 3 | ..... | 0 | 0 | 6 | 9 | 11 | 26 | .....do..... | 2 packages infested sliced plug smoking tobacco. |
| 16 | 17 | 87 | 87 | ..... | 3 | 0 | ..... | × | × | ..... | × | .....do..... | Larvæ and adults in cut plug tobacco placed in sealed glass jars. Examined 1 day after exposure. |
| 16 | 42 | 35 | 35 | 1 | ..... | 0 | 3 | 31 | 100 | 97 | 69 | .....do..... | Granulated smoking tobacco. Examined 2 days after exposure. |
| 17 | 17 | 87 | 87 | ..... | 1½ | × | × | × | × | × | × | .....do..... | Infested cut plug tobacco. Box not wrapped. |

Most of the tests recorded in Table IV were made with the different stages of the beetle in smoking tobacco. In this series the time of exposure to cold varied from 1½ hours to 5 days. The treatment did not prove completely effective on all stages of the beetle at temperatures between 14° and 16° F. with exposures under 5 days. In all experiments under the same conditions exposures of over 5 days gave satisfactory results, all stages of the beetle in various classes of manufactured tobacco being killed. At temperatures below 20° F. the time of exposure in a long series of tests varied from 1½ hours to 56 days. Experiments with infested tobacco exposed for 56 days at temperatures between 33° and 40° F. were not entirely satisfactory, a few larvæ remaining alive. For short exposures it was found that results depended largely upon the insulation afforded by wrapping and upon the quantity of material used. Larvæ within the cells were found to be more resistant to cold than other stages of the insect. After treatment the material used in the experiments was placed in an incubator and kept for some time under observation at a constant temperature of 86° F.

Six additional experiments were made with cigars that were heavily infested. The boxes were wrapped with paper and kept in cold storage in sealed metal containers. The temperature varied from 12° to 20° F., but was fairly constant at 14° F. The time of exposure was 7 days for three experiments, 21 days for one experiment, and 31 days for two experiments. All stages of the beetle, including large numbers of eggs, were present in five lots of cigars. In the experiment in which the time for exposure was 21 days two boxes of 25 cigars each, in which large numbers of newly hatched larvæ had been placed, were used. In all the experiments the treatment proved completely effective. The boxes were kept under suitable rearing conditions at the Richmond laboratory for several months and no reinfestation developed.

At a temperature of approximately 14° F., three separate tests were made with cigarettes. Three boxes containing 100 cigarettes each, heavily infested with adults, larvæ, and pupæ, were utilized, the duration of the experiments being 14, 15, and 42 days respectively. In each lot all stages of the beetle were killed. In another series of experiments 30 separate tests were made with various quantities and classes of manufactured tobacco. The temperature of the cold-storage room was fairly constant, approximating 14°F., the variations during the entire period being from 12° to 18° F., and the relative humidity ranging from 84 to 90 per cent. In these as well as other experiments temperature and humidity records were obtained by means of a self-recording thermograph and hygrograph. Part of the material was exposed in air-tight containers and part exposed in the original containers, not sealed, or in paper-wrapped packages.

The amount of material varied from a few ounces of tobacco up to 20 pounds of loose tobacco or tobacco refuse, and the time of treatment varied from 1½ hours to 30 days. Exposures of over 5 days, in all experiments, gave satisfactory results, the tobacco being completely sterilized. A bale of infested cigar tobacco kept in cold storage for 28 days under the conditions mentioned above at a temperature of approximately 14° F. was found to have been completely freed from all stages of the beetle.

### EFFECT OF COLD STORAGE ON EGGS OF THE TOBACCO BEETLE.

A large number of separate experiments were made with eggs of the tobacco beetle to determine the effect of low temperatures in cold storage. In these experiments eggs were placed in cigars and exposed at temperatures ranging from 12° to 20° F., the length of exposure varying from 24 hours to 16 days. All boxes of cigars were wrapped with paper. After removal from cold storage the material was placed in an incubator and kept at a constant temperature of 86° F. with humidity from 80 to 90 per cent. The checks were kept in the same incubator until the period of incubation had passed. In these experiments none of the eggs exposed to cold hatched, while hatching of the check lots was normal.

In another series eggs on leaf tobacco or in cells on microscope slides were exposed. Exposures to cold were made without special protection such as ordinarily is afforded by the food substance of the insect. Other conditions of the experiments were practically the same as described in the preceding series. The time of treatment ranged from 5 hours to 7 days, with temperatures varying from 14° to 18° F. In most experiments in which the time of exposures was shorter than 24 hours, the temperature was constant at 14° F. Exposures of less than 24 hours did not give satisfactory results, as all or part of the eggs hatched in most of the experiments. In experiments in which the duration of treatment was more than 24 hours all eggs were killed.

### EFFECT OF REFRIGERATION ON QUALITY OF MANUFACTURED TOBACCO.

In order to determine whether or not cold storage seriously injures manufactured tobacco, cigars, cigarettes, and smoking and chewing tobacco were placed in cold storage for periods ranging from 30 to 50 days. The stock used for the experiment was fresh and in good condition. An exact duplicate of each brand was kept for the same period, in perfect condition, in the humidor or storage room at a cigar store. Part of the material put in cold storage was in sealed metal containers and part merely wrapped with paper in

order to avoid sweating which ordinarily would occur upon removal from cold storage. When removed from cold storage it was placed in a dry room for several hours, then placed in the humidor or storage room at the cigar store with the control or check packages. At frequent intervals the treated tobacco was compared with check tobacco by Mr. J. M. Holt, a tobacco expert of Richmond, Va., and the writer. The tobacco put in cold storage seemed in perfect condition in every respect, and could not be distinguished from that which had been kept at the cigar store.

#### ALTERNATIONS OF HEAT AND COLD.

The alternation of a low temperature with a comparatively high temperature is apparently more effective on the tobacco beetle than is a single exposure to cold. During the course of cold-storage investigations at Richmond, Va., in 1914, two lots of badly infested smoking tobacco were put in cold storage for 2 days at temperatures ranging from 14° to 16° F. Lot A was not removed from the storage room, whereas at the end of 24 hours lot B was removed and kept in a warm room for 24 hours, then put back in cold storage for a further period of 24 hours. On March 22, 2 days after treatment, both lots were examined and no live stages of the beetle were found in lot B. In lot A about 90 per cent of the different stages were dead. The tobacco used in the experiments was kept until August 28, 1914, and upon examination lot A was found heavily infested whereas lot B was uninfested.

### HIGH TEMPERATURES.

#### EXPERIMENTS WITH DRY HEAT AS A MEANS OF STERILIZING TOBACCO—TESTS IN TOBACCO FACTORIES.

Two series of tests were made, one at Richmond, Va., in a factory where smoking tobacco is manufactured, and the other at New Providence, Tenn., in a factory in which special processes are used in the preparation of leaf tobacco for export to Africa.

Excellent facilities were secured for determining the effect of high temperatures on different stages of the beetle, and for determining to what extent the tobacco is sterilized by the various processes of manufacture. It was found that in these factories the temperatures reached were sufficiently high to kill all stages of the beetle, reinfestation depending on methods of handling, packing, or storing the manufactured product.

At Richmond, Va. (May, 1915), large numbers of eggs of the tobacco beetle on leaf tobacco and in cells on microscope slides, pupæ, adults, and newly hatched and mature larvæ were placed in boxes

of granulated smoking tobacco and passed during the regular course of manufacture through the drying processses in use in a large factory where smoking tobacco is manufactured. All stages of the beetle were destroyed. In one of the driers a temperature of 180°F. was reached, which is sufficiently high to sterilize the tobacco quickly and effectively.

In the New Providence factory the leaf tobacco, after treatment with vaseline, is compressed into packing cases, placed in drying rooms, and subjected to heat for some time. The maximum temperature reached was found to be about 150°F. This process is used for a certain grade of tobacco shipped to Africa and it is said that little or no damage has ever been reported from mold or insect injury. In the experiments made (Oct. 20–24, 1915) by Mr. A. C. Morgan and the writer to determine the effect of the heating process in destroying the different stages of the tobacco beetle, infested tobacco was placed in the heating room and a continuous record of the temperature obtained by means of a self-recording thermograph. Humidity records were taken at the beginning and close of each experiment. Part of the eggs used were on leaf tobacco on which they had been deposited, and part in cells on microscope slides, and control lots were kept for each of the different stages. In all of the controls development was normal, but it was found that the temperature reached in the heating room resulted in killing all stages of the beetle. The details of several of the experiments are given in Table V.

TABLE V.—*Effect of heat on different stages of the tobacco beetle (Lasioderma serricorne). Experiments at New Providence, Tenn., 1915.*

| Stage of insect. | | | | Relative humidity. | Temperature. | | Time of exposure. | Results. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|
| Eggs. | Larvæ. | Pupæ. | Adults. | | Min. | Max. | | | |
| | | | | *Percent.* | *°F.* | *°F.* | *Hours.* | | |
| 105 | 41 | 8 | 51 | 38–40 | 97 | 140 | 24 | All stages killed. | Eggs 4 and 5 days old. |
| 114 | 10 | 10 | 75 | 38–49 | 101 | 138 | 48 | .....do..... | Eggs 1 day old. |
| 32 | 42 | 10 | 28 | 38–49 | 93 | 140 | 72 | .....do..... | Eggs 1 to 5 days old. |

EFFECT OF HIGH TEMPERATURES ON DIFFERENT STAGES OF THE TOBACCO BEETLE—LABORATORY EXPERIMENTS.

At Clarksville, Tenn. (1916), numerous laboratory experiments were conducted to determine the effect of high temperatures. The incubators or ovens used in making the tests were fitted with water jackets which permitted exposures to be made without much variation in temperature. The different lots were kept with suitable food

in sealed glass tubes for a considerable time after exposure. The eggs used were on leaf tobacco or in cells on microscope slides. Controls were kept corresponding to the different stages. It was found that adults and larvæ become inactive after a few minutes exposure to heat above 117° F., but recover if the temperature is not kept higher than 120° F. for a considerable length of time. An exposure of 1 hour at 140° F. killed all stages of the beetle in small quantities of tobacco but it was found that both larvæ and pupæ are more resistant to heat while in the cells formed before pupation, the cells serving as a protection. The results of several of the experiments are given in Table VI.

TABLE VI.—*Effect of high temperatures on the tobacco beetle.—Laboratory experiments at Clarksville, Tenn., 1916.*

| Stage of insect. | Exposure. | Temperature. | | Results. | Remarks. |
|---|---|---|---|---|---|
| | | Min. | Max. | | |
| | *Hours.* | *°F.* | *°F.* | | |
| Larvæ | 1 | 110 | 115 | Not effective | In leaf tobacco. |
| Adults and larvæ | 1 | 110 | 115 | do | In cigar. |
| Adults | 1 | 117 | 120 | do | Became inactive, but recovered after treatment. |
| Adults and larvæ | 1 | 128 | 130 | do | Part of each stage killed; remainder recovered. |
| Eggs | 1 | 128 | 131 | Effective | None of eggs hatched. Check eggs hatched normally. Eggs 1 day old. |
| All stages | 2 | 130 | 140 | do | Eggs on leaf tobacco. |
| Eggs | ½ | 138 | 140 | do | In cigars. |
| Larvæ | ½ | 138 | 140 | do | Do. |
| Larvæ and pupæ | 1 | 138 | 140 | do | In yeast cake and tobacco. |
| All stages | 1 | 144 | 145 | do | In leaf tobacco. |
| Do | ¾ | 146 | 150 | do | Do. |
| Do | ½ | 158 | 164 | do | Eggs on leaf tobacco. |
| Do | 1 | 158 | 165 | do | Do. |
| Do | ½ | 180 | 181 | do | Do. |

In these tests only a small quantity of the food substance was used. The time required for treatment will therefore depend on the amount and character of the food substance and the insulation furnished by the container or wrapping material. The results of the numerous tests made show that comparatively mild heat, if long continued, is sufficient to kill all stages of the beetle. The temperatures found effective are in no way injurious to certain classes of tobacco, which in many cases are subjected to a much higher degree of heat in the process of manufacture.

### STERILIZING TOBACCO WAREHOUSES BY MEANS OF STEAM.

At Quincy, Fla., in July, 1913, an experiment was conducted by Mr. D. C. Parman, of this bureau, and the writer in a large warehouse. It is the custom of the managers to clean up and sterilize the warehouses as far as possible, usually by fumigation, before the new crop is brought in. The warehouse used for the experiment was empty and the owners wished to ascertain to what extent steam could be employed.

Two tests were made, one in which the room was heated by turning the steam into radiators, and one in which the entire basement of the building was heated by admitting the live steam direct from the boiler. Evaporation during the experiment was about 75 gallons per hour.

The experiment in the room fitted with radiators was commenced on July 7, the temperature of the room being 85° F. Steam was turned on at 2 p. m.[1] All stages of the tobacco beetle were used in the experiment and were placed in cans of smoking and chewing tobacco in the middle of the room. Controls were kept for each lot. At 3.30 p. m. the temperature reached 100° F., and at 4.30 p. m. 117° F. This temperature was held until 6 p. m. and then gradually lessened until 7 a. m., July 8, when it registered 89° F. The steam was again turned on and the temperature gradually increased until, at 10 a. m., it registered 138° F. This temperature was held until noon, when the experiment was ended. At different times some of the material was taken out and the boxes labeled and kept for later examination. Tobacco exposed for 2½ hours at temperatures between 100° and 117° F. when examined on July 8 was found to contain live adults, pupæ, and larvæ. In all material kept in the room during the entire time, and which had been subjected to a temperature of 138° F. for 2 hours, all stages of the beetle were killed. In this experiment the air was dry. A hygrometer at 6 p. m. registered about 35° F.

In the second experiment the entire basement of the building was heated by live steam which was admitted directly through four half-inch nozzles. Three nozzles were fitted to the main steam pipe extending through the basement from end to end, and one nozzle fitted to the return pipe. Records of temperature were secured by means of self-recording thermometers placed in or near the packages of infested tobacco, which were divided into several lots and placed in different parts of the basement. The tobacco used in the experiment was badly infested with all stages of the beetle. The experiment was commenced at noon. The outside temperature in the shade was 92° F. A boiler pressure of 40 pounds was kept until noon of the following day, July 9, when the fire under the boiler was allowed to die out gradually to avoid too sudden cooling of the walls of the building. The tobacco used in the experiment was taken to Tampa, Fla., and kept under observation until July 15. The results were as follows: At temperatures under 114° F., with exposures of 6, 12, and 18 hours, results were practically negative. Exposure at temperatures between 118° and 130° F. for 24 hours killed part of the different stages, but was not entirely effective. Mate-

[1] All references to clock time refer to standard time.

rial was effectively sterilized when exposed for 24 hours in a part of the building where a temperature of 137° F. was reached, and all stages of the beetle were killed.

The tests made show that under certain conditions steam may be used to advantage in sterilizing empty warehouses, as much higher temperatures could easily be obtained than were reached in the experiments. Dry heat, secured by fitting the building or storage room with sufficient radiating surface, would, of course, be the most practical means of heating, as steam turned directly into a room for some time might cause injury to the building by expansion of beams from moisture and heat combined.

Other experiments have shown that temperatures of from 130° to 150° F. result in the death of all stages of the tobacco beetle, and it is probable that very little if any damage to most grades of tobacco would follow. In cleaning storage rooms, etc., live steam or hot water applied through a flexible pipe fitted with a nozzle can often be used to advantage in destroying the insects in refuse or dust in crevices in the floor or walls.

The expense of steaming in the foregoing experiment for 24 hours amounted to $15.20, as follows:

| | |
|---|---|
| Engineer, 2 days @ $4 per day | $8.00 |
| Fireman, 2 days @ $1 per day | 2.00 |
| Fuel | 4.50 |
| Water | .70 |

The expense of fumigating the same space (108,000 cubic feet) with hydrocyanic-acid gas would have amounted to about $75, or with carbon disulphid $60, these estimates being based on prices of chemicals used for fumigation at the time of the experiment.

### USE OF STEAM AS A MEANS OF STERILIZING INFESTED TOBACCO.

Although steam furnishes, under some circumstances, an effective and convenient method of sterilizing storerooms or warehouses there are numerous difficulties which prevent its use in sterilizing infested tobacco. Leaf tobacco becomes more brittle if exposed to steam at high temperatures for any length of time, the texture and aroma are changed, and the color becomes darker. In spite of the general objection against steaming, however, there seems to be considerable evidence that mild steaming may be used to advantage in treating certain classes of cigar tobacco. In the application of steam the principal requisite is that the tobacco does not become too wet, and that unnecessarily high temperatures are avoided.

A method of treating cigar tobacco in revolving steam drums has been tested in the Philippines (77). Steam was applied for 20 minutes at a pressure of about 4 atmospheres, the temperature rang-

ing from 140° to 194° F. The treatment was said to be thoroughly effective in killing all stages of the beetle, and cigars made from the steamed tobacco were pronounced indistinguishable from those made from unsteamed tobacco, the only apparent damage in any instance being that steaming the wrapper tobacco made it darker and somewhat more brittle.

#### EFFECT OF STEAM ON DIFFERENT STAGES OF THE BEETLE—LABORATORY EXPERIMENTS.

At Richmond, Va. (January, 1915), tests were made to ascertain the effect of steaming various classes of tobacco infested with the beetle. Steam under pressure was admitted directly into a tightly closed fumigating drum. Temperature records were obtained by inserting a chemical thermometer through a cork in the lid of the drum. The eggs used were on bits of leaf tobacco. Examinations of the treated eggs were made after the controls had hatched. All tobacco containing other stages of the beetle was put in seperate jars and sealed after treatment. Each lot was kept under observation for several months. The results of the experiments may be briefly summarized. Thirty-minute exposures at 115°F. gave practically negative results. All stages of the beetle were killed by the following exposures: 20 minutes at 160° and 165°F.; 30 minutes at 163°F.; 1 hour at 138° and 150°F.; 40 minutes at 140°F.

#### ULTRA-VIOLET RAYS.

At the request of a firm manufacturing apparatus for ultra-violet sterilization of water, a series of experiments were made to ascertain the effect of ultra-violet rays on different stages of the tobacco beetle and to determine whether or not the process could be successfully used in sterilizing tobacco. Apparatus for the work was installed at the laboratory at Clarksville, Tenn., the equipment consisting of a mercury arc rectifier for transformation of 110-volt, 60-cycle alternating current to 110-volt direct current, and 2 quartz mercury arc burners operated on direct current at 110 volts and consuming 3.5 amperes. The quartz mercury vapor burners, or lamps, were of different types: One was operated at a voltage of 66–67, consuming 3.3 amperes of current, and the other at a voltage of 70–75, consuming 3 amperes of current.[1] To avoid any effect of heat, all exposures were made with the material in a quartz glass container under distilled water kept at normal room temperatures (quartz glass and chemically pure water are transparent to the ultra-violet rays). In experiments with eggs of the tobacco beetle 3 lots were used in each test, arranged as follows: (*a*) Eggs on upper side of leaf tobacco, (*b*) eggs on under-

[1] The burners were operated under a hood to protect the eyes of the operator from injury, and glasses were worn as an additional precaution.

side of leaf tobacco, (*c*) eggs under glass cover. A check was kept for each experiment. It was found that with eggs exposed directly to the rays, without covering as under arrangement (*a*), at a distance of about 8 inches from the quartz mercury arc, an exposure even as short as 30 seconds was effective in sterilizing eggs under two days old. As has been found with Röntgen-ray radiation, the further embryonic development has advanced, the more resistant the eggs become, and longer exposures are required for their successful sterilization. Eggs exposed on the underside of the leaf, arrangement (*b*), and those under a cover of ordinary glass, arrangement (*c*), hatched normally. Ordinary glass has the property of transmitting ultra-violet rays only to a slight degree, its transmission being approximately only one one-thousandth that of quartz glass. It was found that a screen over the eggs, even of the thinnest glass such as is used for cover glasses on microscope slides, was sufficient to protect them completely from the effect of ultra-violet rays. These exposures served as an additional check on the results obtained from direct exposures to the rays. The experiments with the eggs on the underside of the leaf showed that the ultra-violet rays would not penetrate even the thinnest leaf of cured tobacco. This fact makes it impracticable to apply the method in treating infested tobacco.

Although eggs of the tobacco beetle when exposed directly to the ultra-violet rays can be quickly and effectively sterilized, experiments made so far do not indicate that other stages of the beetle are destroyed by the same exposure. Treated larvæ and pupæ completed transformations to the adult stage, and treated adults laid fertile eggs and died off at a normal rate. The effect of more intense radiation or of prolonged exposure of adults, pupæ, and larvæ has not been determined.

In order successfully to treat leaf tobacco containing eggs, it has been suggested that in preparing the leaf for use it might be possible to devise means for smoothing out the leaves and thus make more powerful exposures of ultra-violet rays from all sides while the tobacco passes through an exposure chamber containing the lamps. As it would be extremely difficult, or perhaps impossible, by any mechanical means, to smooth out completely all the creases or wrinkles in the leaf tobacco, and as the rays do not penetrate opaque substances like tobacco, the method, in the opinion of the writer, is not likely to prove entirely effective or practicable, as the eggs of the tobacco beetle ordinarily are deposited in wrinkles of the leaf. The results obtained from several of the experiments with ultra-violet rays are briefly summarized in Table VII.

TABLE VII.—*Effect of exposure of stages of the tobacco beetle (Lasioderma serricorne) to ultra-violet rays. Experiments at Clarksville, Tenn., 1916.*

| Date. | Stage of insect. | Age of eggs. | Current. | Voltage. | Exposure. | | Results. | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Distance from mercury vapor arc. | Time. | Eggs on upper side of leaf; exposure direct. | Eggs on underside of leaf. | Eggs under glass cover. |
| 1916. | | *Days.* | *Amp.* | | *Inches.* | *Min.* | | | |
| July 20 | Eggs..... | 1 | 3.3 | 66–67 | 8 | ½ | None hatched | All hatched... | All hatched. |
| Aug. 11 | .....do..... | 1–2 | 3.3 | 66–67 | 7.5 | ½ | .....do..... | .....do..... | Do. |
| Do... | .....do..... | 4–5 | 3.3 | 66–67 | 8 | ½ | Nearly all hatched. | Hatching normal. | Hatching normal. |
| July 20 | .....do..... | 3 | 3 | 70–75 | 7.5 | 5 | None hatched | .....do..... | Do. |
| July 21 | .....do..... | 2 | 3.3 | 66–67 | 8 | 10 | .....do..... | .....do..... | Do. |
| July 24 | .....do..... | 4 | 3 | 70–75 | 8 | 45 | .....do..... | .....do..... | Do. |
| July 20 | All stages.. | 1 3 | 3.3 | 66–67 | 7.5 | 8 | Exposed directly to rays. Eggs sterilized. No effect apparent on other stages. | | |
| July 24 | Adults and eggs. | 2–3 | 3 | 70–75 | 8 | 5 | Exposed directly to the rays. Eggs sterilized. No apparent effect on adults. Fertile eggs deposited after exposure. | | |

## TRAPPING.

### ATTRACTION TO LEAF TOBACCO.

In cigar factories it has often been noticed that the adult beetles collect on hands of leaf tobacco suspended for the purpose of ascertaining the humidity. Eggs in large numbers frequently can be found on the leaves, and in the rooms where cigars are made or handled young larvæ from these eggs may easily find their way to the cigars. Numerous experiments were made by liberating large numbers of the beetles in a closed room in which hands of leaf tobacco had been suspended about the walls. It was found that a large proportion of the beetles collected on the tobacco. This habit of the insect suggests the possibility, where conditions permit, of trapping the adults in this manner. The tobacco could be collected at frequent intervals and the eggs and beetles killed by heating or fumigating the leaves, and then replaced; thus, instead of being a source of infestation, this tobacco would to a large extent protect the cigars or other material in the room. The method is said to have been tested in a cigar factory in the Philippines and to have shown excellent results (78).

### TRAP LIGHTS.

The movement of adults toward light has been discussed under "Phototropism" (p. 25). Specially constructed trap lights may often be used to advantage in factories or warehouses, and a large number of the beetles destroyed. A very efficient trap can be made quickly and easily by pinning together sheets of sticky fly paper in the form of a cylinder and suspending it around an electric light. The trap is

more effective if the sheets of fly paper are pinned so that the surface on both the inside and outside of the cylinder is sticky. Traps of this type operated in a large tobacco warehouse were under observation for some time and were found to destroy large numbers of beetles (fig. 13). Another form of trap consists of a large globe, such as is used for street lights, placed over a funnel, the lower part of the spout of the funnel opening into a cyanid jar in which the beetles are killed. An electric-light bulb can be used in the globe, or a trap light of the same type can be operated with acetylene or other light. Another method of destroying the beetles consists of placing shallow pans of oil underneath the lights. A heavy odorless oil is best for this purpose in case leaf tobacco, which may take up odors of kerosene or other oils, is stored near by. The traps fitted with cylinders of fly paper will perhaps be found best adapted to most conditions. While adults fly more readily toward blue or blue-violet light than toward red or orange, colored light bulbs or colored screens cut down the intensity of a source of light. Ordinary electric-light bulbs of clear glass of the nitrogen-filled and other types which transmit lights rich in rays of short wave length have been found well adapted to trapping.

FIG. 13.—Arrangement for using sticky fly paper in collecting adults of the tobacco beetle in warehouses.

*Sex of beetles collected at light.*—A sheet of sticky fly paper which had been suspended around an electric light in a tobacco warehouse at Danville, Va., in July, 1911, was examined by Mr. S. E. Crumb. Of 100 beetles that were removed and dissected, 36 were males and 64 females. Four females contained, respectively, 2, 2, 17, and 22 mature eggs. Seventeen females contained immature eggs, half developed or more, as follows: 2, 2, 2, 2, 3, 3, 4, 5, 6, 7, 7, 8, 10, 10, 11, 12, and 36. Forty-three females were without eggs. Approximately 32 per cent of the females contained eggs and 68 per cent of the females did not.

### COLLECTING AT WINDOWS.

As the light becomes dim in late afternoon in infested warehouses or factories the adult tobacco beetles fly to the windows, often collecting in large numbers on the glass and casings. The beetles may

be easily destroyed at such times by brushing them down into pans of water or oil, or onto sheets of sticky fly paper. In a tobacco warehouse visited by the writer the owners make it part of the regular duties of the watchman to visit each window in the building where the beetles collect and sweep them down on sheets of fly paper spread out on the window sills. Immense numbers of the beetles are destroyed in this way at very little cost.

### COLLECTING BEETLES BY SUCTION.

The use of suction fans operated at lights for collecting the beetles in warehouses has been reported. There has been no opportunity to

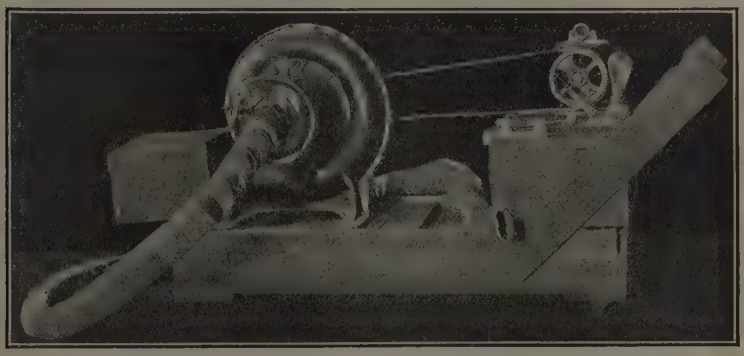


FIG. 14.—Suction fan used for collecting adults of the tobacco beetle in a tobacco warehouse.

test this method. The use of vacuum cleaners operated by electric current might possibly prove to be an effective method of collecting beetles at the windows of warehouses. At Lancaster, Pa., a suction fan was used in one of the large tobacco warehouses. Beetles could be readily drawn from cracks in the building and from about windows, and large numbers were said to have been collected in a short time on several occasions. A photograph of the apparatus used is shown in figure 14.

## OTHER REMEDIES.

### EXPOSURE TO VACUUM.

In 1912, a series of experiments were made at Clarksville, Tenn., by Mr. A. C. Morgan and the writer to ascertain the effect of treating infested tobacco in vacuum. With the apparatus used, a vacuum of about 28.5 inches could be readily obtained. When the air in the vacuum chamber was exhausted the beetles became inactive, but after exposures varying from 1 to 24 hours they again became active when normal air pressure was restored. In some of the experiments a few adults were killed. The eggs hatched normally after exposure. While the experiments with vacuum apparatus alone from a practical

standpoint gave negative results it has been found that the process may be employed in connection with the fumigation of infested tobacco (fig. 15).

### SEALED CONTAINERS FOR MANUFACTURED TOBACCO.

Investigations of factory conditions show that during the process of manufacture tobacco is, in many cases, thoroughly sterilized by heat. In one factory, in which experiments with different stages of the beetle were conducted, the tobacco was subjected to a temperature of 180° F. as it passed through the driers. This degree of heat has been found to destroy all stages of the beetle quickly, and is sufficiently high to sterilize tobacco thoroughly under any ordinary conditions. Tobacco may become infested before it leaves the factory, but it is evident from the usual condition of the tobacco which is returned with complaints of infestation, and from the time required for development of the beetle, that much of this tobacco becomes infested after it leaves the factory.

It is not unusual to find badly infested material in wholesale and retail establishments in the same room used for storing fresh stock. The grubs or larvæ of the tobacco beetle are very minute when hatched, and at this stage are most active and readily find their way through small openings in the boxes or containers. In containers sealed perfectly tight at the factory it is very unusual to find the tobacco injured.

In order to determine whether or not newly hatched larvæ could find their way into uninfested boxes used by different firms for packing smoking tobacco, experiments were made at Richmond, Va., and at Tampa, Fla. The boxes of tobacco were thoroughly sterilized by heat and then put in sealed jars in which eggs of the tobacco beetle were placed at frequent intervals. The boxes were sufficiently tight to exclude partly grown larvæ and the adult beetles, but all showed openings along the edge of the cover and at the hinge of the lid large enough to admit newly hatched larvæ. In the experiments 16 boxes were used and of these 12 boxes became infested after a time whereas none of the control boxes showed the least sign of infestation. In other experiments it was found that some of the larvæ hatching from eggs placed in empty boxes of the same kind escaped through even the smallest openings along the edges of the cover or at the hinges of the boxes.

### CASING CIGAR TOBACCO IN A DECOCTION OF TOBACCO STEMS.

Soaking tobacco stems in water from 12 to 24 hours gives a solution which is said to hasten fermentation of leaf tobacco. Several cigar manufacturers, both in this country and in Cuba, have re-

ported that when this solution was used in casing stripped tobacco there was in some cases a noticeable decrease in the number of infested cigars. It was suggested that the quicker and higher fermentation destroys some of the eggs or other stages of the beetle and that the solution may have a toxic effect when applied externally. No exact data have been secured as to the efficiency of the remedy.

#### USE OF COLD WATER IN CASING CIGAR TOBACCO.

Several cigar manufacturers have reported some success in preventing infestation of finished cigars by casing the leaf in cold water and thoroughly shaking out the tobacco before it is used.

#### BORIC ACID.

Boric acid has been used as a remedy for the tobacco beetle, but to what extent and with what success is not known. In a letter received by the Bureau of Entomology in 1909 from an importer of leaf tobacco in Boston, Mass., reference is made to the use of this remedy in Cuba, it being stated that a 5 per cent solution of boric acid [$B(OH_3)$] used in the water in which tobacco is cased before packing will prevent the tobacco from becoming wormy. The effect of boric acid on the quality of the tobacco has not been determined, but it is probable that no serious injury would occur if used in as dilute a solution as described. Both boric acid and borax are known to have some insecticidal value, and the treatment of manure piles with borax has proved effective against the larvæ of the house fly.[1]

While preliminary tests made with boric acid indicate that it has a toxic effect on larvæ of the tobacco beetle, there has been no opportunity to make tests of the substance on cigar tobacco in the manner mentioned above, nor to determine whether or not the remedy has any practical value in preventing or controlling infestation.

## PREVENTIVE MEASURES.

In cigar stores and comparatively small establishments it is not a difficult matter to eradicate the tobacco beetle. By means of different remedies, infested stock may be treated and the building thoroughly cleaned. The humidors, or storage closets, should be perfectly tight and infested stocks promptly destroyed or treated as soon as signs of infestation are noticed.

In large factories and tobacco warehouses, however, complete eradication in many instances is extremely difficult, or perhaps impossible. The factories are in some cases old wooden buildings, roughly built, and containing innumerable cracks and crevices in

[1] U. S. Dept. Agr. Buls. 118, 245, and 408.

which tobacco dust and refuse have accumulated. These places make ideal hiding and breeding places for the beetles. Even in modern factories of brick or concrete construction it is difficult to eradicate the insect completely after it has once become established, but it is very much easier to keep such buildings clean and free from accumulations of refuse in which the beetles may breed. The measures to be employed in eradication work in sterilizing buildings will depend largely on local conditions.

For destroying the different stages of the beetle in crevices of floors or walls, live steam applied through a nozzle from movable pipes or hose, hot water, gasoline, carbon disulphid, dilute ammonia, paradichlorobenzene, or other suitable substances may be used. Suction cleaners may also be employed to advantage for such work. In cigar factories the stock of leaf tobacco should be kept in a tight or screened room, located as far as possible from the rooms in which the cigars are made or handled. Trays of unsorted cigars should be covered or preferably kept overnight in a screened compartment, as eggs deposited on the cigars at this time may be the cause of heavy loss afterwards.

In sections of the country where severe freezing occurs in winter the doors and windows of warehouses or other buildings in which tobacco is stored may be thrown open and the tobacco subjected to low temperatures. This control measure has been employed by tobacco men in different localities, and when severe freezing weather occurred excellent results were reported.

#### OPEN STORAGE OF LEAF TOBACCO.

The modern method of storing leaf tobacco in hogsheads in specially constructed buildings or sheds, giving practically out-of-door conditions and variations of temperature, furnishes an effective means in cool climates of reducing or preventing injury from the beetle to the classes of leaf tobacco which may be stored in this manner.

#### SOURCES OF INFESTATION IN FACTORIES.

In cigar and tobacco factories the greater number of beetles are brought in with the leaf tobacco. Factories are in some instances in close proximity to tobacco warehouses where beetles are present in large numbers. A comparatively small number of beetles in a room in which cigars are made, however, or in rooms where the cigars or other classes of manufactured tobacco are packed, are sufficient to infest the stock seriously. The protection of the finished product before it is packed is generally of more importance than the condition of the raw material, as the process of manufacture wholly or partly frees it from different stages of the beetle which were present in raw material.

### FUMIGATION.

Fumigation is now generally employed as a means of destroying certain classes of insects, and is a standard remedy against insects which damage stored products and those infesting mills and factories.

The tobacco beetle has been found to be exceedingly resistant to fumigants. Numerous experiments have shown that it is necessary to use much stronger dosages of fumigants in treatment of this beetle than are employed usually against other insects. The insulation afforded by the pupal cells and by the compactness of food substances seems to protect the contained larvæ or pupæ from the action of the fumigant. In many instances only a small percentage of the tobacco-beetle larvæ survives treatment, but adults transforming from these small numbers serve to reinfest tobacco if it is kept for any length of time.

*The properties and characteristics of the various chemicals used for fumigation should be thoroughly understood in every particular by the operator in order that necessary precautions may be taken and the work properly done.* The treatment is simple, however, easily applied, and fairly effective.

### Fumigation with Hydrocyanic-acid Gas.

In generating hydrocyanic-acid gas in fumigation sodium cyanid (NaCN), or potassium cyanid (KCN), sulphuric acid ($H_2SO_4$), and water are necessary. The hydrocyanic-acid gas, which is the killing agent, is produced by the action of the sulphuric acid (diluted with water) on the sodium or potassium cyanid. The cyanid is usually employed in the crystal form. It is now sold in molds weighing 1 ounce each. When small quantities are used, this form is best, as it avoids the trouble and danger of weighing. A high grade of cyanid should be used for fumigation, as the presence of adulterants greatly reduces the amount of hydrocyanic-acid gas evolved. Potassium cyanid should be guaranteed to be 98 or 99 per cent pure. A high grade of sodium cyanid should be used which is guaranteed to contain not less than 51 per cent cyanogen. Commercial sulphuric acid, sp. gr. 1.84 or 66° Baumé, which is approximately 93 per cent pure, is commonly used for fumigation.

### DANGER ATTENDING USE.

*Hydrocyanic-acid gas and the chemicals employed to produce it are extremely dangerous, and as hydrocyanic-acid gas is fatal to human beings if breathed in any quantity considerable care is necessary in its use.* Sodium cyanid and potassium cyanid are violent and fatal poisons if taken internally, and sulphuric acid produces burns when

coming in contact with the skin. When the chemicals are handled with care and all details of the method understood, however, there is no special danger and the method has been used in insect control for many years with few records of serious accidents.

### EFFECT OF HYDROCYANIC-ACID GAS ON THE QUALITY OF TOBACCO.

Hydrocyanic-acid gas is slightly lighter than air and all traces of the gas are quickly removed from the tobacco by thorough airing.

In order to determine whether or not any deposition of cyanogen in the cigars occurs as a result of the cyanid treatment different lots of freshly made cigars were fumigated at Key West, Fla., in 1912, and sent to the Bureau of Chemistry, United States Department of Agriculture, for examination. A list of the different lots of cigars sent is shown in Table VIII.

TABLE VIII.—*Effect of hydrocyanic-acid gas on quality of cigars. Fumigation tests at Key West, Fla.*

| Date fumigated. | Cyanid of potash to 100 cubic feet of space. | Exposure. |
|---|---|---|
| 1912. | *Ounces.* | *Hours.* |
| Apr. 20 | 8 | 24 |
| May 4 | 8 | 24 |
| May 10 | 4 | 48 |
| May 29 | 4 | 24 |
| June 8 | 8 | 36 |
| June 14 | 8 | 24 |
| June 18 | 8 | 24 |
| Not fumigated. (Used as check on treated lots.) | | |

All lots of cigars were exposed to the air for a short time after fumigation, and then sealed. As the amount of potassium cyanid used was greater than is ordinarily employed in fumigation, the test was a severe one. The cigars were received by the Bureau of Chemistry on July 8. The following report was received on November 12, 1912, from Mr. R. E. Doolittle, acting chief of the Bureau of Chemistry: "We have made a careful examination of the eight samples of cigars submitted by you on July 8 last, and we are unable to detect the slightest trace of hydrocyanic acid in any of the samples."

Samples of cigars fumigated by the cyanid process and untreated cigars of the same brand were submitted to a number of expert cigar men at Key West, Fla., in order to ascertain if fumigation in any way affected the flavor or quality of the cigars. All reported that no difference between the treated and untreated cigars was apparent, the uniformity of burn, capacity for retaining a light, and color of ash appearing normal.

PREPARATIONS FOR FUMIGATION.

The fumigating closet or box should be perfectly tight to prevent escape of gas. In fumigating storage rooms or warehouses all openings should be closed and the windows and doors arranged so that they may be opened from the outside when the building is aired. *Do not enter the room until it is thoroughly aired.* The cubic contents of the closet, room, or box to be fumigated should be determined, so that the exact quantity of the different chemicals needed may be known. Food supplies that may be stored in the building should be removed, as moist foods, such as meats and vegetables or fruit, may absorb or retain the gas.

Care must be taken in fumigating large warehouses in close proximity to dwellings, as the liberation of a vast quantity of hydrocyanic-acid gas may endanger the persons within.

For generators use stoneware or crockery jars. They should be sufficiently deep that the liquid will not boil over when the gas is generated.

Hydrocyanic-acid gas is lighter than air. For this reason *place the generator underneath the material to be fumigated or on the floor of the room.* Whenever the room or building is of large size it is advisable to use two or more generators, limiting the amount of cyanid to 2 or 3 pounds in any one generating jar. The jars should be of small diameter in order that the cyanid may be completely covered by the acid and water.

PROCESS OF FUMIGATION.

The chemicals used in generating hydrocyanic-acid gas are placed in the generating jar in the following order: *First, water; then sulphuric acid; last, just before closing the fumigating closet or building, the cyanid.* Measure into the generating jar the proper amount of water, then add the acid slowly in the proper amount. Considerable heat will be developed by the addition of the acid, and for this reason it is best not to mix the water and acid until just before the cyanid is put in, as the heated liquid will act more quickly on the cyanid. The water and acid should be mixed as directed above. *Do not pour water into acid.* Severe burns may result from the ebullition or sputtering of the liquids if the order of mixing the water and acid is reversed. The acid should be kept in glass-stoppered bottles. Cyanid should be kept tightly sealed, as it deteriorates rapidly when exposed to the air. For convenience the cyanid may be put into thin paper sacks and these dropped into the generating jar. This method is applicable if large dosages are used; if only a small quantity of the cyanid is required, however, it is not best to use a paper wrapper, as the generation of the gas is somewhat retarded. An

enameled dipper has been found convenient in placing the cyanid in the generators. *The reaction of the chemicals is extremely rapid, and the generation of the deadly gas begins at once.* In fumigating large buildings, where a considerable number of generators are required, the operator should have several assistants. In such cases it is best to have the proper amount of cyanid in paper sacks placed beside the jars holding the acid and water. Begin dropping the cyanid in the jars farthest from the door first, going from one jar to the next as rapidly as possible.

#### TEMPERATURES FAVORABLE FOR EFFECTIVE FUMIGATION.

In using fumigants for the control of the tobacco beetle, best results have been secured in warm weather and at temperatures above 70° F. Under 60° or 65° F. the beetles are more or less dormant and while in this condition are considerably more resistant to the action of the gas.

#### DOSAGES TO USE.

*Sodium cyanid* (*NaCn*).—This substance when pure liberates nearly one-third more hydrocyanic-acid gas per pound than does potassium cyanid and at present it is more generally used for fumigation.

Sodium cyanid should be combined with acid and water to generate the hydrocyanic-acid gas according to the following formula:

| | | |
|---|---|---|
| Sodium cyanid (grade guaranteed to contain not less than 51 per cent cyanogen) | avoirdupois ounce | 1 |
| Sulphuric acid (commercial) | fluid ounces | 1½ |
| Water | fluid ounces | 8 |

Use multiples of the formula given above to secure the dosage desired. Fumigate for 24 hours. The dosage to use will depend upon the penetration required. For general use 4 ounces of the cyanid to 100 cubic feet will be found satisfactory. (This dosage requires 4 ounces of the cyanid, 6 fluid ounces of acid, and 12 fluid ounces of water.) For baled or closely packed tobaccos a somewhat heavier dosage may be used, or the time of exposure increased. An increase of the amount of cyanid above 4 ounces per 100 cubic feet, however, has not greatly increased the effectiveness of the treatment in many instances.

*Potassium cyanid.*—Should potassium cyanid be used in place of the sodium cyanid, it should be combined with the sulphuric acid and water according to the following formula:

| | | |
|---|---|---|
| Potassium cyanid (98–99 per cent) | avoirdupois ounce | 1 |
| Sulphuric acid (commercial) | fluid ounce | 1 |
| Water | fluid ounces | 8 |

For every 100 cubic feet of space use multiples of this formula to secure the dosage desired. The dosage used may be the same as with sodium cyanid. It will be noted that the amount of acid required with potassium cyanid is less than with sodium cyanid.

In using either potassium cyanid or sodium cyanid for fumigating, a greater amount of water than that given in the formulas should not be used, as any quantity of water above 3 fluid ounces for each ounce of cyanid results in a smaller yield of hydrocyanic-acid gas.

In preparing chemicals for fumigation the cyanid is *weighed*, and the acid and water are *measured*. The time of exposure has been found to be an important factor in fumigation and it is not advisable to make the time less than 24 hours, unless the vacuum process of fumigating is employed. A comparatively small dosage with a long exposure appears to be as effective as is a heavier dosage with a shorter exposure.

### SUMMARY OF RESULTS OF FUMIGATION EXPERIMENTS.

A brief summary of the average results obtained in a series of 34 fumigating experiments with material infested by the tobacco beetle follows. Different dosages of sodium cyanid varying from 1 to 8 ounces per 100 cubic feet of space were used. The time of treatment was 24 hours. The tests were made during July, August, and September, the maximum temperatures varying from 82° to 92° F. and the minimum temperatures from 42° to 72° F. All stages of the beetle in leaf tobacco, in different classes of manufactured tobacco, and in pressed yeast cake, were utilized. Part of the eggs, for convenience in making examinations, were placed in cells on microscope slides, and part were located on the original leaf tobacco on which they had been deposited. The eggs used were from 1 to 6 days old. Multiples of the 1-1½-3 formula were used with the sodium cyanid. The results obtained with different dosages were as follows:

*Dosage 1 ounce per 100 cubic feet of space.*—In three experiments only a few eggs hatched. In these embryonic development was nearly complete at the time of treatment. Newly hatched larvæ were nearly all killed, about 4 per cent in dense tobacco survived, and of the other stages, including adults, pupæ, and fully developed larvæ, about 22.3 per cent survived treatment.

*Dosage 1.5 ounces per 100 cubic feet of space.*—In four experiments eggs and newly hatched larvæ were killed. Approximately 21 per cent of other stages survived treatment. The adults remaining alive were mainly those which had not emerged from the pupal cells.

*Dosage 2 ounces per 100 cubic feet.*—This treatment destroyed eggs and newly hatched larvæ. In four experiments 18.6 per cent of the other stages survived.

*Dosage 2.5 ounces per 100 cubic feet.*—This gave somewhat better results. In one experiment all stages were killed. In three experiments all unprotected adults and newly hatched larvæ were killed. Of the other stages approximately 11.8 per cent survived.

*Dosage 3 ounces per 100 cubic feet.*—In four experiments this gave practically the same results as the 2½-ounce dosage.

*Dosage 4 ounces per 100 cubic feet.*—In six experiments this dosage killed eggs, newly hatched larvæ, and practically all unprotected stages. Approximately 9 per cent of the larvæ, pupæ, and adult stages within the pupal cells survived treatment. In one of the six experiments all stages were killed.

*Dosage 6 ounces per 100 cubic feet.*—Practically the same results were shown in five experiments with the 6-ounce dosage. Eggs, newly hatched larvæ, and unprotected adults were killed. About 9.4 per cent of the other stages, mainly mature larvæ protected by dense substances or by the pupal cells, survived. In two of the five experiments all stages were killed.

*Dosage 8 ounces per 100 cubic feet.*—In four experiments with an 8-ounce dosage about 10 per cent of the protected stages survived. All adults which had emerged from the pupal cells and all eggs, newly hatched larvæ, and unprotected larvæ and pupæ were killed. In one experiment all stages were killed.

The results obtained in other experiments made by Mr. Joseph Smith and the writer at Clarksville, Tenn., with both sodium cyanid and potassium cyanid in amounts from 1 ounce up to 8 ounces per 100 cubic feet did not differ materially from those obtained with sodium cyanid in the series described. With both substances, in many instances, an increased dosage above 4 ounces per 100 cubic feet did not show a very decided increase in effectiveness, possibly due to the inability of the gas to penetrate dense food substances or pupal cells.

### DOUBLE FUMIGATION.

Fumigation under most circumstances has not been found entirely effective in sterilizing tobacco, as a few of the insects in either the larva, pupa, or adult stage, protected by the pupal cells or by dense food substances, are apt to survive. In comparatively few of the experiments were the beetles completely exterminated. While a single treatment may be fairly satisfactory, since the few live stages left will require considerable time to increase to sufficient numbers to reinfest the tobacco badly, it is desirable under some circumstances to give a second treatment later in order to destroy the beetles remaining after the first treatment. This can be accomplished easily after the beetles have emerged from the pupal cell. With tobacco kept at ordinary room or summer temperatures the second fumigation should be given about two or three weeks after the first treatment, as by this

time most of the beetles will have emerged from the cells, and the adults, eggs, or newly hatched larvæ then present can be easily destroyed by fumigation. In two of the experiments already referred to, a second treatment was given 12 days later, resulting in the complete extermination of the beetles. Similar results were secured in several experiments not included in the series of tests described.

### FUMIGATING IN A VACUUM.

In cooperation with the Federal Horticultural Board, a series of experiments was conducted at Washington, D. C., to determine the

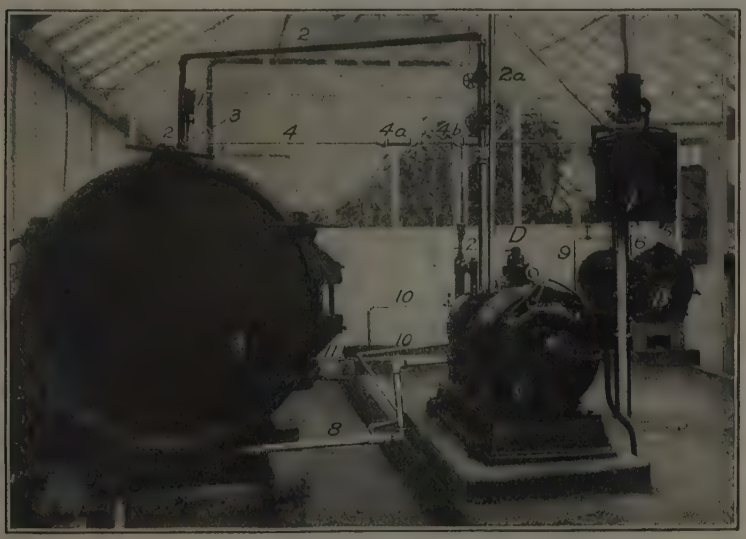



FIG. 15.—Apparatus used for fumigating in partial vacuum.

effects on the tobacco beetle of hydrocyanic-acid gas in the presence of a partial vacuum. The apparatus used for the work was designed by Mr. E. H. Sasscer, Chief Inspector of the Federal Horticultural Board.[1] (Fig. 15.)

By means of vacuum apparatus a very much greater penetration of the gas can be secured than is possible in fumigating at normal air pressure. It has been found in the tests made by the Federal Horticultural Board that hydrocyanic-acid gas when applied in vacuum readily penetrates to the interior of closely compressed bales

[1] A detailed description of the apparatus and process of fumigation in vacuum has been given by the designer, Mr. E. R. Sasscer, in Service and Regulatory Announcements, Federal Horticultural Board, for October, 1915.

of imported cotton. This shows a degree of penetration beyond anything likely to be found in the fumigation of hogsheads or bales of leaf tobacco, or of cigars, or other classes of manufactured tobacco. The exposures found effective with vacuum apparatus in destroying several other species of insects have not proved effective, however, in destroying all stages of the tobacco beetle. A series of 19 experiments with different amounts of sodium cyanid varying from 1 ounce to 6 ounces per 100 cubic feet of space, with an exposure of 1 hour and 45 minutes at a vacuum of about 25 inches; and a series of 14 experiments with 1, 3, and 6 ounces of sodium cyanid to 100 cubic feet of space, with an exposure of 2 hours and 30 minutes at a vacuum of approximately 25 inches, did not show the process, under the conditions specified above, to be more effective than fumigation with the same dosages for 24 hours at normal air pressure.[1] All stages of the tobacco beetle were used in the experiments. These were in baled cigar tobacco, in various classes of manufactured tobacco, and in pressed yeast cakes and tobacco refuse. The principal advantage shown was the gain in time, as large quantities of manufactured tobacco can be quickly treated by the vacuum process. It is thought that changes in the present method of vacuum fumigation will make the process better adapted to the treatment of tobacco. A repetition of treatment in the majority of instances will be found necessary for complete sterilization.

### Fumigation with Carbon Disulphid.

Carbon disulphid ($CS_2$) is quite generally used for the destruction of the insect pests which infest grain, food products, etc., and has been used extensively in control of the tobacco beetle. It is a colorless liquid about one-fourth heavier than water, extremely volatile, evaporating with great rapidity when exposed to the air. If the temperature of the air is high and the evaporating surface large the rate of evaporation is increased. In the liquid state it is inflammable, but not explosive, and can be safely handled if the cans are kept perfectly tight and away from the fire. The vapor takes fire in the air at about 200° F. under certain conditions. It is a violent and dangerous explosive when mixed with air in the proportion of 1 volume of vapor to approximately 14.3 volumes of air, in the presence of fire of any kind, or at a temperature without flame of about 300° F. The vapor is considerably heavier than atmospheric air. For this reason carbon disulphid when used for fumigating should be placed at the *top* of the fumigating compartment, if possible *above* the material to be treated. *Care must be taken not to inhale the fumes, as the gas is*

[1] In the above experiments the writer was assisted by Mr. H. L. Sanford, of the Federal Horticultural Board, and by Mr. J. L. Webb, of the Bureau of Entomology.

*poisonous*. All traces of the fumigant quickly disappear from the substance treated when exposed to the air, and even foodstuffs have been treated without affecting their edibility in any way. Tobacco or cigars when properly aired do not retain the odor of the gas, and the quality and flavor are not perceptibly changed.

While carbon disulphid is not as effective as hydrocyanic-acid gas, the ease with which it may be employed makes it the more desirable fumigant, particularly when the material to be fumigated occupies a small space. The liquid carbon disulphid has merely to be poured into a shallow dish, placed near the ceiling of the compartment to be fumigated, and allowed to evaporate. The method is a favorite one with many cigar dealers, the main objection being the danger of fire. A dealer known to the writer, in fumigating small lots of infested stock, makes use of an old refrigerator so fitted that the door closes perfectly tight. This is placed in a building outside the cigar store, to avoid danger of fire and for convenience in airing after treatment. As soon as infested stock is detected it is fumigated promptly, and in this case there has been small loss from the tobacco beetle.

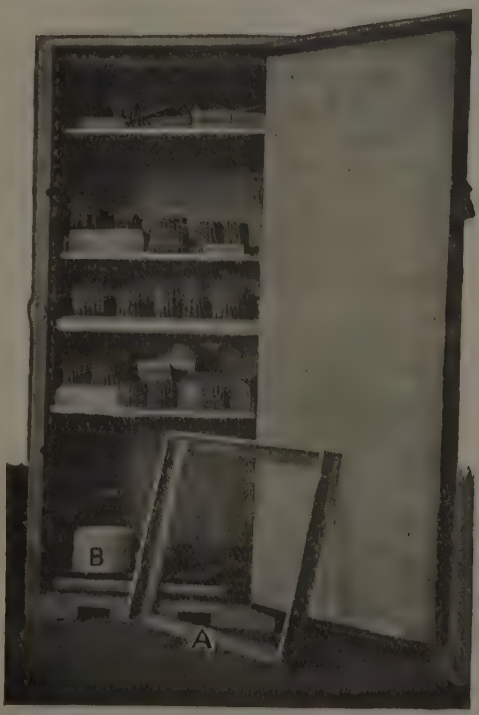



FIG. 16.—A closet for fumigating cigars or manufactured tobacco. *A*, Removable tray for holding cigars; *B*, generating jar.

The fumigating closet, shown in figure 16, was found to be a convenient size for cigar fumigation. Its dimensions are 2.5 by 2.5 by 6.5 feet. The sides are of matched boards. The inside is lined with sheet zinc. The door and fastenings are similar to those commonly used on refrigerators. Strips of heavy felt were attached where the edges of the door fitted. Boat clamps were used at top and bottom

to insure perfect fitting of the door. The closet was fitted with removable trays to insure easy and rapid handling of the cigars. The trays have bottoms of one-half-inch wire screen.

Fumigation is more effective when the temperature is high, and it is not advisable to use carbon disulphid when the air temperature is much below 70° F. To be fairly effective against all stages of the beetle in tobacco, carbon disulphid should be used at a rate of not less than 4 pounds to 1,000 cubic feet of space. When only a small space is to be fumigated and the cost of the treatment is consequently slight, the exact amount of the carbon disulphid used is of no particular importance, even if the amount is very much in excess of the dosage advised above. The period of exposure should be from 24 to 48 hours. The results obtained in a number of experiments with carbon disulphid are given in Table IX. The time of exposure was 24 hours, except in experiments 5 and 11, in which the time of exposure was 48 hours.

TABLE IX.—*Experiments with carbon disulphid in control of the tobacco beetle (Lasioderma serricorne). Experiments at Clarksville, Tenn., 1915.*

| Exp. No. | Date. | Dosage (rate per 1,000 cu. ft.). | Stage of insect. | Placement. | Results. |
|---|---|---|---|---|---|
| | 1915. | *Pounds.* | | | |
| 1 | Aug. 3 | 1 | Larvæ and adults | In smoking tobacco | Partially effective. |
| 2 | Aug. 4 | 1 | Adults, larvæ, and pupæ | do | Do. |
| 3 | Sept. 16 | 2 | Larvæ (87) | In pressed yeast cake | 3 days after treatment, 16 alive, 71 dead. |
| 4 | Sept. 4 | 2 | Larvæ (73) | In wire cage, no protection. | All killed. |
| 5 | Sept. 3 | 3 | Larvæ | In plug tobacco | 2 days after treatment, 4 alive, 26 dead. |
| 6 | Aug. 20 | 3 | Adults, larvæ, and pupæ | In glass tubes with cloth cover. | All killed. |
| 7 | Aug. 9 | 3 | All stages | do | Do. |
| 8 | Sept. 18 | 4 | Larvæ (22) | In cigars | 2 days after treatment, all dead. |
| 9 | Sept. 22 | 4 | All stages | In smoking tobacco | No live stages found 2 days after treatment. Eggs did not hatch. Check eggs hatched normally. |
| 10 | Aug. 9 | 5 | All stages | In cigars and refuse tobacco. | All stages killed. |
| 11 | Aug. 17 | 5 | Eggs | About 50 on leaf tobacco. | Eggs did not hatch. Check eggs hatched normally. |
| 12 | Sept. 26 | 10 | Eggs and larvæ | In cigars | Cigars kept for 6 months. No signs of infestation. |

### FUMIGATING WITH CARBON TETRACHLORID.

Carbon tetrachlorid ($CCl_4$) has been used to a considerable extent as a substitute for carbon disulphid in fumigation. It is not as efficient an insecticide as carbon disulphid, heavier dosages are required, and the cost of treatment is greater. The substance is noninflammable, however, and owing to this property is convenient for use when only a small space is to be fumigated where there might be danger

of fire or explosion if carbon disulphid were used. When pure, carbon tetrachlorid is a thin, oily fluid, and in the open air quickly evaporates. It is heavy (sp. gr. 1.599), transparent, colorless, and has a pungent odor—not, however, as disagreeable as in the case of carbon disulphid.

For fumigating it is used in the same manner as carbon disulphid, being evaporated from shallow pans placed *over* the substance treated. The evaporating area of the pans holding the liquid should be large. As with carbon disulphid, an exposure of from 24 to 48 hours should be given. Tests made with carbon tetrachlorid in quantities up to 5 pounds per 100 cubic feet did not give satisfactory results in sterilizing tobacco. As carbon tetrachlorid is more likely to be employed in small compartments it is well to use very heavy dosages, as the increase in cost will be slight. The killing effect is greater when the air temperature is high.

### Formaldehyde as a Fumigant.

Tests were made of 40 per cent formaldehyde at the rate of 2½ ounces to 100 cubic feet of space. All stages of the tobacco beetle were used and the formaldehyde was vaporized by means of heat. The substance at this strength was found to be only partially effective.

### The effect of Röntgen or X rays on the tobacco beetle.

The effect of the X rays on the higher animals, including human beings, is well known. Sensitiveness to the rays has been found by different investigators to vary with the species of animal. Newly formed, especially embryonic tissues, have been found to be more easily affected by exposure to the rays than are those more mature. Certain bodies of cells are remarkably susceptible, their functions being retarded, modified, or completely inhibited, although morphologically they are apparently normal. The rays are known to have a marked effect on the reproductive organs, prolonged exposure causing an animal to become temporarily or permanently sterile. In general it may be said that when living tissues of an animal are exposed to the action of the rays, the functions of the cells are retarded or depressed, and permanent injury, or even the eventual death of the animal, may result. The exact effect of the rays depends upon the intensity of the radiation, the duration of the exposure, and the distance of the organism exposed from the source of radiation. When the energy input through a Röntgen tube is great, the intense radiation resulting is correspondingly more active, and more injurious to living tissue, producing more marked physiological results. Exposure to rays of great intensity has been shown to retard or stop growth, differentiation and regeneration,

and to interfere with the processes of cell division or multiplication, causing, in some cases, degenerative changes to take place or a decrease in the rate of cell division. On the other hand, an exposure of slight intensity or short duration may be without perceptible effect, or may even be accelerative, and perhaps increase the rate of cell division. It seems to be well established that the effects of repeated exposures to the rays are to a certain extent cumulative, an exposure of say 5 milliampere minutes having identically the same effect, whether the exposure is given in one treatment or in several treatments applied at different times so that the total exposure amounts to 5 milliampere minutes. The effect of the rays on the simpler forms of animal and plant life has been studied by numerous investigators and in general their action seems to be the same as on the higher animals.

The X-ray process of treating tobacco has been exploited commercially for sterilizing cigars infested with the tobacco beetle, and satisfactory results have been reported. Improvements in the method of treatment and in the apparatus have been made from time to time, and the modern forms of Röntgen tubes used make possible continuous and unchanging Röntgen ray radiation of great power and intensity. Effects can now be obtained which were not possible or practicable in commercial work with the earlier forms of apparatus.

During 1912 experiments were made by Mr. A. C. Morgan and the writer (76) with apparatus designed to sterilize cigars on a commercial scale. The experiments, from a practical standpoint, gave negative results. Later experiments made with apparatus capable of producing and maintaining a much more powerful radiation have shown that the earlier tests failed to give satisfactory results owing to the comparatively light exposures obtainable with the apparatus then used.

A brief statement of the results obtained by the writer (86) in a series of experiments conducted under laboratory conditions at Schenectady, N. Y., in 1915, is presented.[1] These experiments were a continuation of investigations of a similar nature commenced at Tampa, Fla. In previous experimental work it had been found in sterilizing cigars or tobacco that light dosages are ineffective from a practical standpoint. To be effective the radiation must be intense, and it is evident that if the process can be applied successfully to commercial work the apparatus used must be capable of producing and maintaining such radiation during the entire period of exposure.

The results obtained in the experiments have been briefly summarized as follows:

[1] A detailed report of these experiments has been published (86).

Under laboratory conditions tests made with a Röntgen-ray tube permitting a high-energy input and giving an intense and powerful radiation produced results which promise that the X-ray process may be used successfully in treatment of cigars or tobacco infested with the tobacco or cigarette beetle.

Heavy dosages must be given, as is indicated by the results of exposures given in several series of experiments.

In treatment of the egg stage, heavier exposures are required to sterilize eggs which are near the hatching point than are required to sterilize eggs newly laid.

In experiments performed by the writer a dosage equivalent to 150 milliampere minutes exposure with a spark gap of 5.5 inches gave satisfactory results with eggs in tobacco placed 7.5 inches from the focal spot of the tube. With this exposure the eggs in which embryonic development was well advanced hatched, but in all cases where these larvæ were kept under observation they failed to reach the adult stage.

The minimum lethal dosage at a given distance from the focal spot of the Röntgen tube used was not determined.

In two separate experiments adults were given an exposure of 600 milliampere minutes (amperage × time), with a spark gap of 5.5 inches, giving an approximate voltage of 65,000. The distance from the focal spot of the Röntgen tube was 7.5 inches. The results were as follows:

(1) No effect on length of life was apparent, as the beetles died at about the same rate as the same number of beetles kept as check.

(2) Large numbers of eggs were deposited after exposure. These eggs were infertile. Eggs laid by the check beetles hatched normally.

Larvæ were given an exposure of 600 milliampere minutes, other conditions of the experiment being the same as in the experiments with adults given above. While no immediate effect was apparent the treatment had the effect of stopping activity and development, the larvæ remaining in a dormant condition for a prolonged period. All treated larvæ died before reaching the pupa stage.

Two methods of treating cigars in factories with the X-ray process are employed at the present time. In one method the finished cigars in closed boxes are conveyed by a belt very slowly through an exposure chamber containing the Röntgen tubes. The walls of the exposure chamber are constructed of thick sheets of lead (lead is not penetrated by the Röntgen rays) in order to protect the operator of the machine from injury.

In the other method of treatment a large room used as a humidor at the factory was completely lined with sheet lead. In a narrow compartment within the humidor, extending along one side, a series of 16 powerful Röntgen-ray tubes are arranged in two lines

extending from end to end, and placed so that the rays penetrate the humidor from various angles. A rotary fan forces cold air through the tube compartment and over the tubes, keeping the temperature of the humidor normal. The finished cigars in closed boxes are placed on a long shelf extending along the partition of fibrous material (permeable to the rays) separating the tube compartment from the rest of the humidor. An exposure of 42 minutes is given by an automatic control of current. Cigars are left on the shelf until all space is taken up, then placed in other parts of the humidor, where they are kept until shipped out. This arrangement gives a minimum exposure, close to the Röntgen tubes, of 42 minutes. Ordinarily the method of handling gives many repeated exposures, on the shelf close to the tubes or at distances farther out in the humidor. A test of this process was made by the writer on November 7, 1916, to determine the effect on the egg stage of the tobacco beetle. About 200 eggs deposited on leaf tobacco were placed in a sealed cigar box and treated. An equal number of eggs were kept as a check. The eggs treated were placed in the humidor 7½ feet from the wall of the tube compartment and given three periods of 42 minutes' exposure; then placed on the shelf directly in front of the tubes and given one period of 42 minutes' exposure. This gave a total of three accumulative periods of 42 minutes each 7½ feet from the nearest tube and one period of 42 minutes on the shelf close to the tube compartment. By November 18 most of the check eggs had hatched, but all of the treated eggs were more or less shrunken and none had hatched.

## SUMMARY AND RECOMMENDATIONS.

The tobacco beetle, a stored-product insect, is practically cosmopolitan and occurs wherever large quantities of leaf or manufactured tobacco are handled or stored. It attacks a variety of dried substances, its most common food being tobacco.

In tobacco factories, the principal sources of infestation of the finished products are:

(1) Infested leaf tobacco brought into the factory.

(2) Tobacco warehouses, where beetles are present in large numbers, close to the factory.

(3) Infested tobacco, refuse material, cigars, or manufactured tobacco which has accumulated. (Beetles breeding from this material quickly spread to all parts of the factory.)

A very few beetles present in storage or packing rooms in factories may be the cause of serious loss, by depositing their eggs on the finished product. The protection of the product at this time is usually of more importance than the condition of the raw material, since the leaf tobacco in most cases is partly or completely freed from

different stages of the beetle by handling or by the process of manufacture. Whenever possible manufactured tobacco should be packed in insect-proof containers.

The more important means of controlling the tobacco beetle may be summarized briefly as follows:

(1) Scrupulous cleanliness in the factory, wholesale or retail establishment, including the prompt destruction or treatment of all refuse material, damaged stock, etc., in which the beetles may breed.

(2) In factories, screening or otherwise protecting the finished product from infestation.

(3) Constructing or refitting packing or storage rooms, especially in warm localities, so that they can be quickly and easily cleaned, and with a view to the exclusion of beetles which may be present in other parts of the factory.

Among destructive agencies which may be employed in control of the insect are:

(1) Freezing. (Treatment by cold storage or exposure to low temperatures in cold climates.)

(2) High temperatures or steam. (A temperature of from 125° to 140° F. continued for several hours, or 150° F. for a short time, kills all stages of the beetle.)

(3) Trapping or destruction by mechanical means.

(4) Fumigation with carbon disulphid, hydrocyanic-acid gas, or other fumigants.

(5) Sterilization of infested tobacco by means of exposure to Röntgen or X rays.

The modern method of storing leaf tobacco in hogsheads in specially constructed buildings or sheds, giving practically out-of-door conditions and variations of temperature, furnishes an effective means, in cool climates, of reducing or preventing injury from the beetle to the classes of leaf tobacco which may be stored in this manner.

## BIBLIOGRAPHY.

(1) Fabricius, J. C.
1792. Entomologia systematica, v. 1. Hafniae.
Page 241: Original description as *Ptinus serricornis*.

(2) ———
1801. Systema eleutheratorum, v. 1. Kiliae.
Page 230: *Ptinus serricornis* described as living in American dried plants.

(3) Schönherr, C. J.
1808. Synonymia insectorum, v. 1, pt. 2. 424 p. Stockholm.
Page 113: *Ptilinus serricornis*, synonymy.

(4) Duftschmid, Caspar.
1825. Fauna Austriæ, pt. 3. 289 p. Linz.
Page 46: *Ptilinus testaceus* described as new.

(5) STEPHENS, J. F.
1833. Nomenclature of British insects. ed. 2. 136 columns. (Printed in double column.) London.
*Lasioderma testaccum.*

(6) ————
1832. Illustrations of British entomology, v. 5, Mandibulata. 447 p. London.
Page 417: *Lasioderma testaceum,* description. Genus *Lasioderma* defined.

(7) STURM, JACOB.
1837. Deutschland Fauna in Abbildungen nach der Natur mit Beschreibungen. V. Die insecten, Bd. 11, p. 89, pl. 237. Nürnberg.
*Xyletinus testaceus.*

(8) DEJEAN, P. F. M. A.
1837. Catalogue des coléoptères. Ed. 3. 176 p. Paris.
Page 129: *Xyletinus flavescens* Dahl. listed as synonym and *serricornis* as distinct.

(9) STURM, JACOB.
1843. Catalog der Käfer-Sammlung. 386 p. 6 pl. Nürnberg.
Page 84: *Xyletinus serricornis, Xyletinus testaceus* listed as distinct.

(10) REDTENBACHER, LUDWIG.
1849. Fauna Austriaca. Die käfer. 883 p., 2 pl. Wien.
Page 353: *Xyletinus testaceus,* description.

(11) GUÉRIN-MÉNÉVILLE, F. E.
1850. Enumeration des insectes qui consomment les tabacs. *In* Revue et Magasin de Zool., ser. 2, v. 2, p. 426–442, pl. 8.
Pages 431–438: *Xyletinus serricornis.* Distribution and food habits. In tobacco from North America and Cuba. Originally from North America. Often found in Europe. Besides tobacco often feeds on various other dried vegetable substances.

(12) BACH, MICHAEL.
1856. Käferfauna für Nord. und Mitteldeutschland, v. 3, 1856–1859. Coblenz.
Page 115: *Xyletinus testaceus.*

(13) CHEVROLAT, AUGUSTE.
1861. Observations et notes synonymiques. *In* Ann. Soc. Ent. France, ser. 4, v. 1, p. 390–392.
Page 390: *Xyletinus serricornis* given as synonym of *Catorama pallida* Germ. Mentions tobacco as food. Species acclimated in all parts of the world. Mentions a predacious beetle.

(14) MULSANT, M. E., and REY, CL.
1864. Histoire naturelle des coléoptères de France, Terediles. 391 p., 10 pl. Paris.
Page 307: *Pseudochina* (*Hypora*) *serricornis.* Detailed description and synonymy.

(15) LECONTE, J. L.
1865. Prodromus of a monograph of the species of the tribe Anobiini, of the family Ptinidæ, inhabiting North America. *In* Proc. Phila. Acad. Nat. Sci. for 1865, p. 222–244.
Page 238: *Lasioderma serricorne.* Description and synonymy. Brief note on distribution and food habits. Species carried by commerce over the whole globe. Lives chiefly, though not exclusively, upon tobacco.

(16) GEMMINGER, MAX, and HAROLD, B.
1869. Catalogus coleopterorum, v. 5. Monachii.
Page 1781: *Lasioderma serricorne,* synonymy.

(17) WALSH, B. D., and RILEY, C. V.
1869. Drug-store pests. *In* American Ent., v. 1, no. 7, p. 147.
Brief account of food habits.

(18) CHEVROLAT, AUGUSTE.
1880. Description d'un cléride. *In* Bul. Soc. Ent. France, ser. 5, v. 10, p. xxxi–xxxii.
*Tanerocleruś girodi*. Original description.

(19) GORHAM, H. S.
1880–86. Malacodermata. *In* Biologia Centrali-Americana. Insecta Coleoptera, v. 3, pt. 2. 372 p., 13 col. pl. London.
Page 199: *Lasioderma serricorne*, distribution. Gives habitat and synonymy. Europe, Hungary, Germany, England, Spain, United States, and Mexico.

(20) SCHWARZ, E. A.
1883. Insects affecting drugs. *In* Canadian Ent., v. 15, no. 7, p. 140.
Brief account of the food habits and injury to drugs.

(21) ATKINSON, G. F.
1885–86. The cigarette beetle (Lasioderma serricorne Fab.) *In* Jour. Elisha Mitchell Sci. Soc. Raleigh, 1885–86, p. 68–73.
Account of the occurrence, habits, and life-history of the species and means of control.

(22) ————
1889. The cigarette beetle (Lasioderma serricorne Fab.). *In* So. Car. Agr. Expt. Sta. Bul. 4, new ser., p. 73–79.
An account of occurrence, habits, and food substances. Description of egg, larva, cocoon. Length of larval stage. Mentions an unknown chalcid parasite.

(23) SCHWARZ, E. A.
1889. Lasioderma serricorne. *In* U. S. Dept. Agr. Div. Ent. Insect Life, v. 1, no. 11, p. 357.
Brief note.

(24) RILEY, C. V., and HOWARD, L. O.
1889. Lasioderma serricorne injuring cigarettes. *In* U. S. Dept. Agr. Div. Ent. Insect Life, v. 1, no. 12, p. 378–379.
Mention of carbon disulphid as remedy.

(25) COOK, A. J.
1889. A new clothes beetle. *In* Ann. Rept. Ent. Soc. Ont. 20, p. 41.
Description of adult and account of injury to plush-covered furniture.

(26) ————
1889. Report of entomologist. *In* Ann. Rept. Mich. Agr. Expt. Sta. 2, p. 88–103.
Pages 92–93: An account of the habits of the beetle and injury to plush-covered furniture. Description of adult and remedies. Gives as remedies gasoline and carbon disulphid.

(27) SCHWARZ, E. A.
1890. Notes on the tobacco beetle (Lasioderma serricorne). *In* Proc. Ent. Soc. Wash., v. 1, no. 4, p. 225–226.
Mention of preference of beetle for certain kinds of tobacco.

(28) TRYON, HENRY.
1890. The tobacco beetle. *In* Agr. Gaz. N. S. Wales, v. 1, p. 273–277.
Mention of injured cigars from India, Manila, and Havana. Mentions benzine as a remedy.

(29) RILEY, C. V., and HOWARD, L. O.
1890. The cigarette beetle. *In* U. S. Dept. Agr. Div. Ent. Insect Life, v. 2, nos. 11 and 12, p. 368–369.

(30) TARGIONI-TOZZETTI, A.
1891. Animali ed insetti del tabacco in erba e del tabacco secco. 346 p., 100 fig. Firenze-Roma.
Pages 89–91, fig. 38: Gives synonymy and describes and figures larva and adult of the tobacco beetle (*Lasioderma serricorne*). Gives an account of the distribution and concludes that its original home may be America.

(31) RILEY, C. V.
1892. Lasioderma serricorne. *In* Sci. Amer., v. 66, no. 2, p. 21.
Gives an account of the cigarette beetle. Gives steaming as best means for killing larvæ and eggs.

(32) SMITH, J. B.
1893. Notes on some ptinid pests. *In* Ent. News, v. 4, no. 10, p. 325–328. 4 fig.
Species compared with the drug-store beetle, *Sitodrepa panicea*. Original figures of both species given with a description of their characters.

(33) RILEY, C. V., and HOWARD, L. O.
1893. On remedies for the "cigarette beetle." *In* U. S. Dept. Agr. Div. Ent. Insect Life, v. 5, no. 3, p. 198.

(34) KELLICOTT, D. S.
1894. Some museum and granary pests. *In* Jour. Columbus Hort. Soc., v. 9, no. 9, p. 11–12.
Mention among museum and granary pests.

(35) HOPKINS, A. D., and RUMSEY, W. E.
1896. Practical entomology. West Va. Agr. Expt. Sta. Bul. 44, p. 245–324.
Page 307: Brief notes on cigarette beetle and remedies. List of food substances given.

(36) SMITH, J. B.
1896. Economic entomology. 481 p., 483 fig. Philadelphia.
Pages 193–194, fig. 181–182: The tobacco or cigarette beetle—a general account of the insect.

(37) CHITTENDEN, F. H.
1896. Insects affecting cereals and other dry vegetable foods. *In* U. S. Dept. Agr. Div. Ent. Bul. 4 (new ser.), p. 112–131.
Pages 126–127: The cigarette beetle. List of products affected by the tobacco beetle.

(38) BORDAGE, EDMUND.
1897. Sur deux coléoptères. *In* Revue Agricole . . . de l'Ile Maurice, v. 11, p. 281–283.
An account of the beetle having been found for the first time in tobacco in Paris in 1848 by M. Planche, inspector of tobacco factories. Gives list of food substances. Mentions injury to silk and plush hangings. [Reference not corroborated.]

(39) KIESENWETTER, V. von, and SEIDLITZ, GEORGE, ed.
Naturgeschichte der insecten Deutschlands, v. 5, Hälfte 1. Berlin.
Pages 150–151: *Lasioderma testacea*. Description, synonymy. Mentions species as probably native to America. Found most commonly in tobacco in Hamburg, Berlin, and Leipzig. Spread by commerce to large part of Europe, especially to Germany.

(40) QUAINTANCE, A. L.
1898. Insect enemies of tobacco in Florida. Fla. Agr. Expt. Sta. Bul. 48, p. 155–188, 16 fig.
Pages 175–178: Cigarette beetle (*Lasioderma serricorne* Fab.). Notes on occurrence and damage to tobacco. Gives an account of food habits and describes method of treatment with carbon disulphid.

(41) LUGGER, OTTO.
1899. Fifth annual report of the entomologist. . . Minnesota for 1899. 247 p., 6 pl. St. Paul.
Pages 67–69: Brief account of this and other ptinids.

(42) HOWARD, L. O.
1899. Principal insects affecting the tobacco plant. *In* U. S. Dept. Agr. Yearbook for 1898, p. 121–150, fig. 7–31.
Pages 144–145, fig. 29–30: A general account of the cigarette beetle. Mentions steaming and other means of control.

(43) ———
1900. Principal insects affecting tobacco. U. S. Dept. Agr. Farmers' Bul. 120. 32 p., 25 fig.

(44) HINDS, W. E.
1901. Fumigation with carbon bisulphide. *In* U. S. Dept. Agr. Div. Ent. Bul. 30 (new ser.), p. 78–82.

(45) HOWARD, L. O.
1902. Recent injury by the cigarette beetle. *In* U. S. Dept. Agr. Div. Ent. Bul. 38 (new ser.), p. 94–96.
Mention of injury caused by the cigarette beetle in different localities.

(46) OSBORN, HERBERT.
1902. Note on the occurrence of the cigarette beetle in Columbus. *In* Ohio Nat., v. 3, no. 2, p. 330–331.
Food habits and description of larvæ and adults. Mention of injury to plush-covered furniture.

(47) SANDERSON, E. D.
1902. Insects injurious to staple crops. 295 p. New York.
Pages 237–238: Description and account of habits, and remedies for cigarette beetle.

(48) CHITTENDEN, F. H.
1902. Principal injurious insects in 1902. *In* U. S. Dept. Agr. Yearbook for 1902, p. 726–733.
Page 728: An account of injury in 1901 in Virginia, Ohio, New York, Indiana, and Washington, D. C., by *Lasioderma serricorne*.

(49) OSBORN, HERBERT.
1903. Insects of the season in Ohio. *In* U. S. Dept. Agr. Div. Ent. Bul. 40 (new ser.), p. 46–47.
Notes on occurrence in upholstered furniture in Ohio.

(50) CHITTENDEN, F. H.
1903. The principal injurious insects of 1903. *In* U. S. Dept. Agr. Yearbook for 1903, p. 563–566.
Page 563: Mention of injury by *Lasioderma serricorne* in Maryland, Virginia, Florida, and the District of Columbia.

(51) SYMONS, T. B.
1904. Entomological notes for the year in Maryland. *In* U. S. Dept. Agr. Div. Ent. Bul. 46 (new ser.), p. 97–99.
Mention of injury in Maryland and of control experiments with carbon disulphid and hydrocyanic-acid gas.

(52) ———
1905. Common injurious and beneficial insects of Maryland. Maryland Agr. Expt. Sta. Bul. 101, p. 125–204.
Pages 173–174: *Lasioderma testaceum* Dufts. An account of food habits and remedies.

(53) CHITTENDEN, F. H., and PRATT, F. H.
1905. An experience with hydrocyanic-acid gas as a remedy for the cigarette beetle in dwellings. *In* U. S. Dept. Agr. Div. Ent. Bul. 54, p. 68–70.
An account of injury to furniture in the District of Columbia and of control experiments in dwellings with hydrocyanic-acid gas.

(54) CHITTENDEN, F. H.
1905. Principal injurious insects of 1905. *In* U. S. Dept. Agr. Yearbook for 1905, p. 628–636.
Page 630: The cigarette beetle said to have been gradually increasing in destructiveness in spite of remedial measures adopted. Mentions injury to upholstered furniture.

(55) VAN DINE, D. L.
1905. Insect enemies of tobacco in Hawaii. Hawaii Agr. Expt. Sta. Bul. 10, 16 p.
Pages 14–16: Mention of injury to stored products. Carbon disulphid given as a remedy.

(56) BRITTON, W. E.
1907. Insect enemies of the tobacco crop in Connecticut. *In* Sixth report of the State entomologist of Connecticut, 1906, p. 263–279.
Pages 278–279: *Lasioderma testaceum* Dufts. Brief notes describing injury to cigarettes and tobacco. Mentions fumigation with carbon disulphid as a remedy.

(57) SIMPSON, C. B.
1906. The cigarette beetle (Lasioderma serricorne). *In* Transvaal Agr. Jour., v. 4, no. 15, p. 625–626.
Notes on life history, introduction into Transvaal, damage and means of control.

(58) CHITTENDEN, F. H.
1906. Principal injurious insects of 1906. *In* U. S. Dept. Agr. Yearbook for 1906, p. 508–517.
Page 516: Notes on the occurrence of insects throughout the Eastern United States to Arizona. Mentioned as injuring herbarium specimens in St. Louis and upholstered furniture in the District of Columbia, West Virginia, and New Jersey.

(59) SMITH, J. B.
1907. Drug and cigar beetles. *In* N. J. Agr. Expt. Sta. Bul. 203, p. 33–37.
Mention of different food substances.

(60) CHITTENDEN, F. H.
1907. Principal injurious insects of 1907. *In* U. S. Dept. Agr. Yearbook for 1907, p. 541–552.
Page 552: Brief mention of injury to tobacco, drugs, seeds, and furniture by the cigarette beetle.

(61) HOOKER, W. A.
1907. Observations on insect enemies of tobacco in Florida in 1905. *In* U. S. Dept. Agr. Bur. Ent. Bul. 67, p. 106–112.
Page 111: Brief mention of occurrence in Florida.

(62) UNITED STATES DEPARTMENT OF AGRICULTURE, BUREAU OF ENTOMOLOGY.
1909. Principal injurious insects of the year 1908. *In* U. S. Dept. Agr. Yearbook for 1908, p. 567–580.
Page 579: Mention of the cigarette beetle as general in tobacco warehouses and increasing in destructiveness.

(63) FELT, E. P.
1909. Control of household insects. New York State Mus. Bul. 129. 47 p.
Page 40: Brief mention of *Lasioderma serricorne*.

(64) RUNNER, G. A.
1909. Report on tobacco insect investigations. *In* Va. Polytech. Inst. Agr. Expt. Sta. Ann. Rept. for 1909–10, p. 40–43.
Page 43: Mention of injury to cured tobacco.

(65) HORNE, WM. T.
1909. Tobacco insects. *In* Second report, pt. 1, Secretaria de agricultura, comercio y trabajo de la Republica de Cuba, p. 81–82.
An account of damage and food habits of the tobacco beetle. Carbon disulphid and hydrocyanic-acid gas mentioned as remedies.

(66) METCALF, Z. P.
1909. Insect enemies of tobacco. No. Car. Dept. Agr. Special Bul. 72 p.
A general account of the tobacco beetle and mention of usual remedies. Gasoline is mentioned as useful in sterilizing storage compartments.

(67) SMITH, J. B.
1909. Insects of New Jersey. 888 p. Trenton.
Page 306: *Lasioderma serricorne*. Brief mention.

(68) HERZOG, P. H.
1910. Notes on the "cigarette beetle." *In* Jour. Econ. Ent., v. 3, no. 2, p. 198–202.
An account of fumigation experiments made with hydrocyanic-acid gas. Mentions use of suction fans for destroying adults of the beetles.

(69) POOK, GUSTAV.
1910. Die Anwendung von Kälte zur Verwichtung des Tabakwurms. *In* Chemiker-Zeitung, Jahrg. 34, no. 126, p. 1127.
Report concerning experiments in sterilizing tobacco by means of cold in a perfectly dry room.

(70) MORGAN, A. C.
1910. Insect enemies of tobacco in the United States. *In* U. S. Dept. Agr. Yearbook for 1910, p. 281–296, 15 fig., pl. 20–22.
Pages 291–292, pl. 20: An account of the methods of treatment with fumigants.

(71) BLATCHLEY, W. S.
1910. On the Coleoptera known to occur in Indiana. 1385 p. Indianapolis. (Indiana Dept. Geol. and Natural Resources Bul. 1.)
Page 875: *Lasioderma serricorne* Fab. Description of adult and general account of species.

(72) WOLCOTT, A. B.
1910. Notes on some Cleridae of Middle and North America, with descriptions of new species. Chicago, p. 339–401. (Field Mus. Nat. Hist. Pub. 144, Zool. Ser., v. 7, no. 10.) (See p. 363, 364.)

(73) FELT, E. P.
1910. Control of flies and other household insects. N. Y. State Mus. Bul 136. 53 p.
Page 46: Brief mention of *Lasioderma serricorne*.

(74) MACKIE, D. B.
1911. The tobacco beetle and a method for its control. *In* Philippine Agr. Rev., v. 4, no. 11, p. 606–612, fig. 1, pl. 4.

(75) SANDERSON, E. D.
1912. Insect pests. 684 p., 513 fig. New York.
Pages 239–240, fig. 172: Brief account of *Lasioderma serricorne*.

(76) MORGAN, A. C., and RUNNER, G. A.
1913. Some experiments with Röntgen rays upon the cigarette beetle, Lasioderma serricorne Fabr. *In* Jour. Econ. Ent., v. 6, no. 2, p. 226–230.
An account of experiments made with apparatus designed to sterilize tobacco by means of Röntgen rays.

(77) JONES, C. R.
1913. The cigarette beetle (Lasioderma serricorne Fabr.) in the Philippine Islands. *In* Philippine Jour. Sci., Ser. D, v. 8, no. 1, p. 1–39, 9 pl.
An extended account of the tobacco beetle, giving results of life history studies and experiments with fumigants and other means of control under cigar-factory conditions.

(78) MORGAN, A. C.
1913. An enemy of the cigarette beetle. *In* Proc. Ent. Soc. Wash., v. 15, no. 2, p. 89.
Brief account of *Thaneroclerus girodi* Chevr.

(79) FULLAWAY, D. T.
1914. Tobacco insects in Hawaii. Hawaii Agr. Expt. Sta. Bul. 34. 20 p.
Pages 18–20: An account of damage to tobacco and stored products. Control measures recommended are fumigation with hydrocyanic-acid gas and carbon disulphid and storage at low temperatures.

(80) HERRICK, G. W.
1914. Insects injurious to the household. 470 p. New York.
Pages 292–294: *Lasioderma serricorne*. Brief account of insect. Life history and habits.

(81) HOWARD, L. O.
1914. Report of the entomologist 1914. 16 p. *In* U. S. Dept. Agr. Rpt. for 1914, p. 182–198.
Pages 6–7 (188–189): Control of cigarette beetle by ammonia gas.

(82) O'KANE, W. C.
1914. Injurious insects. 414 p. New York.
Page 370: Brief account of *Lasioderma serricorne*. Fumigation advised as means of control.

(83) DEBUSSY, L. P.
1915. Dierkundige afdeeling. *In* Meded. Deli Proefstat., Medan, v. 9, no. 4, p. 112–121.
Pages 119–120: Lasioderma.

(84) RICHARDS, P. B.
1915. Methods and materials for the control of insect pests. *In* Agr. Bul. Fed. Malay States, v. 4, no. 2, p. 33–42.

(85) RITCHIE, A. H.
1915. Insects pests on tobacco. *In* Jour. Jamaica Agr. Soc., v. 19, no. 11, p. 429–433.
Control of the cigarette beetle by fumigation with carbon disulphid. Advises dosage of 4 pounds per 1,000 cubic feet with an exposure of 48 hours.

(86) RUNNER, G. A.
1916. Effect of Röntgen rays on the tobacco, or cigarette, beetle and the results of experiments with a new form of Röntgen tube. *In* U. S. Dept. Agr. Jour. Agr. Res., v. 6, no. 11, p. 383–388.
Report of studies conducted in continuation of those previously noted.

(87) MACKIE, D. B.
1916. Destruction of the tobacco beetle (Lasioderma serricorne). *In* Trop. Agr. [Ceylon], v. 46, no. 3, p. 170–171.
Results of experiments in fumigating cigars with carbon disulphid in vacuum. Double fumigation required to free product entirely from the pest.

(88) MASON, C.
1916. Report of the government entomologist. *In* Ann. Rpt. Dept. Agr. Nyassaland for the year ended 31st March 1916, p. 19–22.
Mention of the tobacco beetle.

(89) RUNNER, G. A.
1917. The tobacco beetle and how to prevent damage by it. U. S. Dept. Agr. Farmers' Bul. 846. 22 p., 7 fig.
Description of the tobacco beetle, life history, habits, and methods of control.

(90) DAVEY, W. P.
1917. The effect of X rays on the length of life of Tribolium confusum. *In* Jour. Experimental Zool., v. 22, no. 3, p. 572–592.
Mention of experimental work with X rays on *Lasioderma serricorne*.

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